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RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

PRELIMINARY DESIGN REVIEW BROCHURE

7 April 1972

GENERAL DYNAMICS
Convair Aerospace Division
San Diego operation

Space Division
North American Rockwell

TRW
SYSTEMS GROUP

Bendix

0
INTRODUCTION

The Research & Applications Modules Phase B study is a fifteen-month program with final documentation of the analytical portion of the study due at the end of twelve months and selected continuing studies completed at the end of the fifteenth month.

The objective of the proposed work is to define a family of shuttle-compatible payload carriers that provide economical experiment/payload accommodations for realization of practical applications.

This briefing covers the preliminary design of the selected RAM concepts with major emphasis on the design, operations and missions of the sortie RAM and the free-flying RAM.

The study is being performed for the George C. Marshall Space Flight Center by a contractor team led by the Convair Aerospace Division of General Dynamics and supported by the Space Division of North American Rockwell in the areas of manned operations and support systems, TRW Systems in the areas of scientific payload requirements and electronic and fluid subsystems, and Bendix in the areas of scientific payload requirements and electronic subsystems. In addition, certain European companies, Saab-Scania of Sweden and Erno and Messerschmidt-Bolkow-Blohn of West Germany, will generate supplementary data in the areas of data processing/image motion compensation, computer trade studies, phased-array antennas, electrical power, thermal control, and solar arrays as part of the selected continuing studies.

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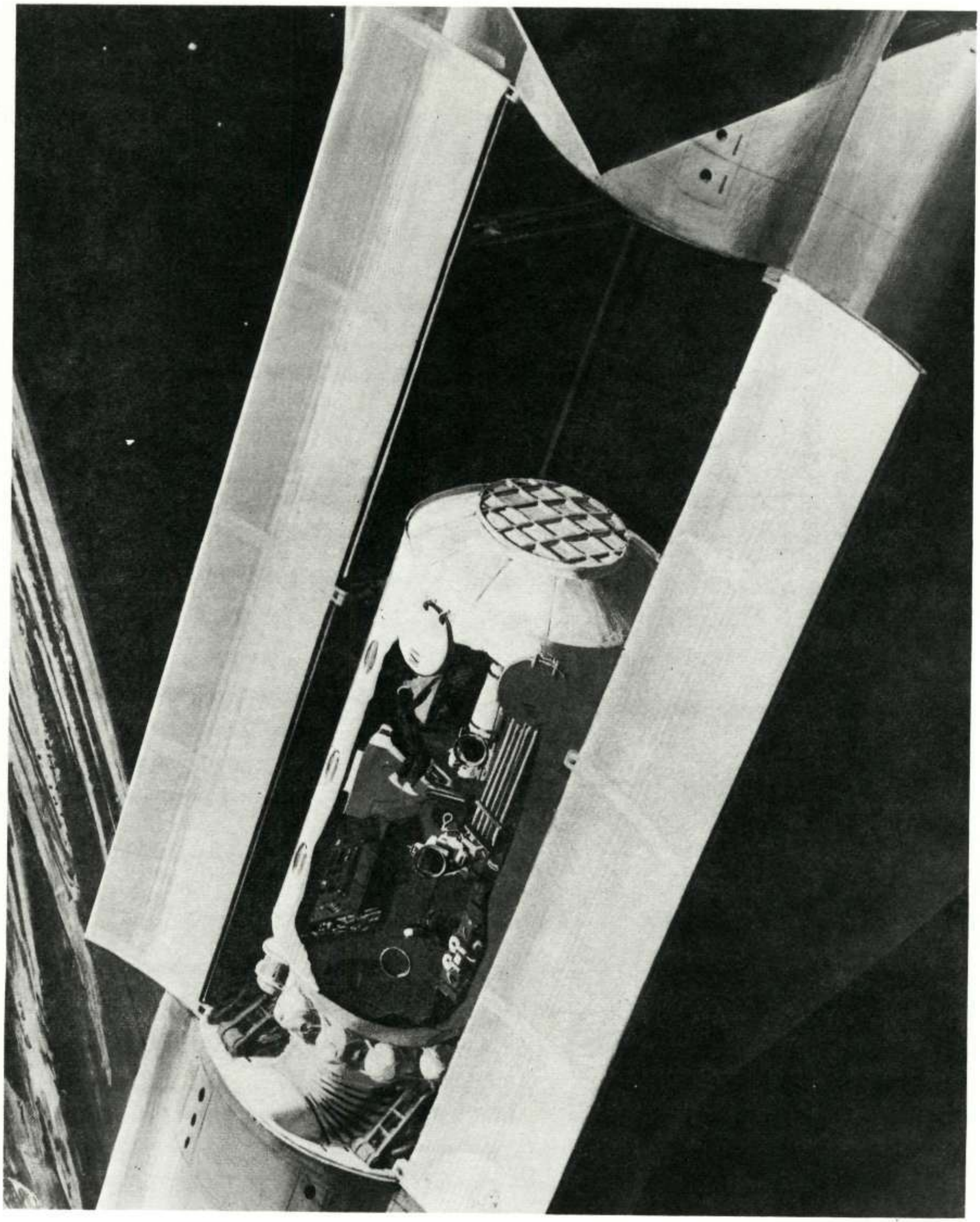
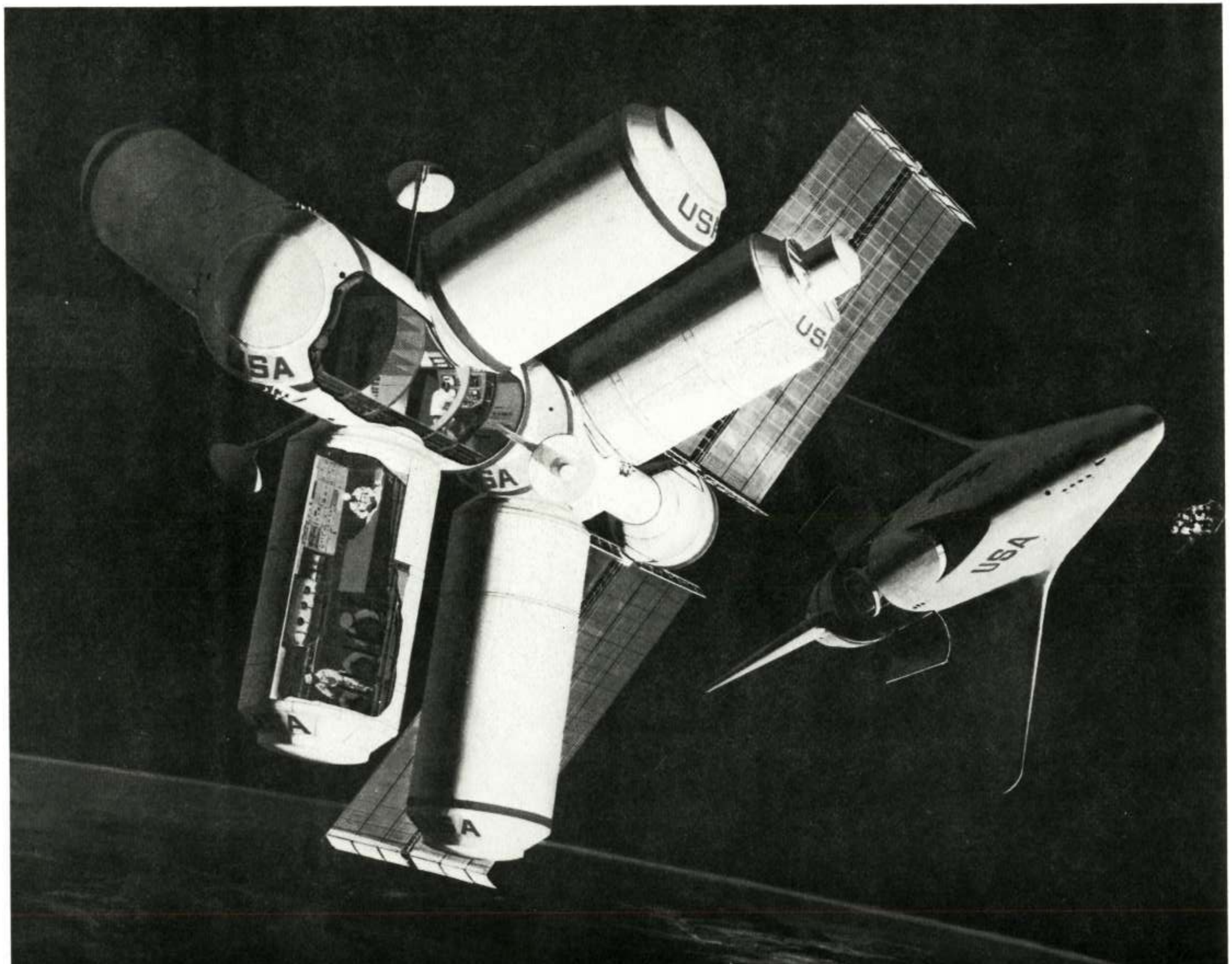
7 April 1972

Prepared by
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
San Diego, California




USA

AGENDA

This presentation places major emphasis upon the design, operations, and missions of the sortie RAM and free-flying RAM hardware elements.

The study goals and objectives and the extent of their implementation will be covered in the summary along with recommendations to better ensure maximum operational use of the combined Shuttle/RAM systems.

The speakers and their participation in the study are:

W.W. Withee	RAM Study Program Director
D.J. Powell	RAM Study Chief Engineer
A.H. Ryan	RAM Study Manager, Mission & Operations Analysis
G. Karel	RAM Study Manager, Systems Design

AGENDA

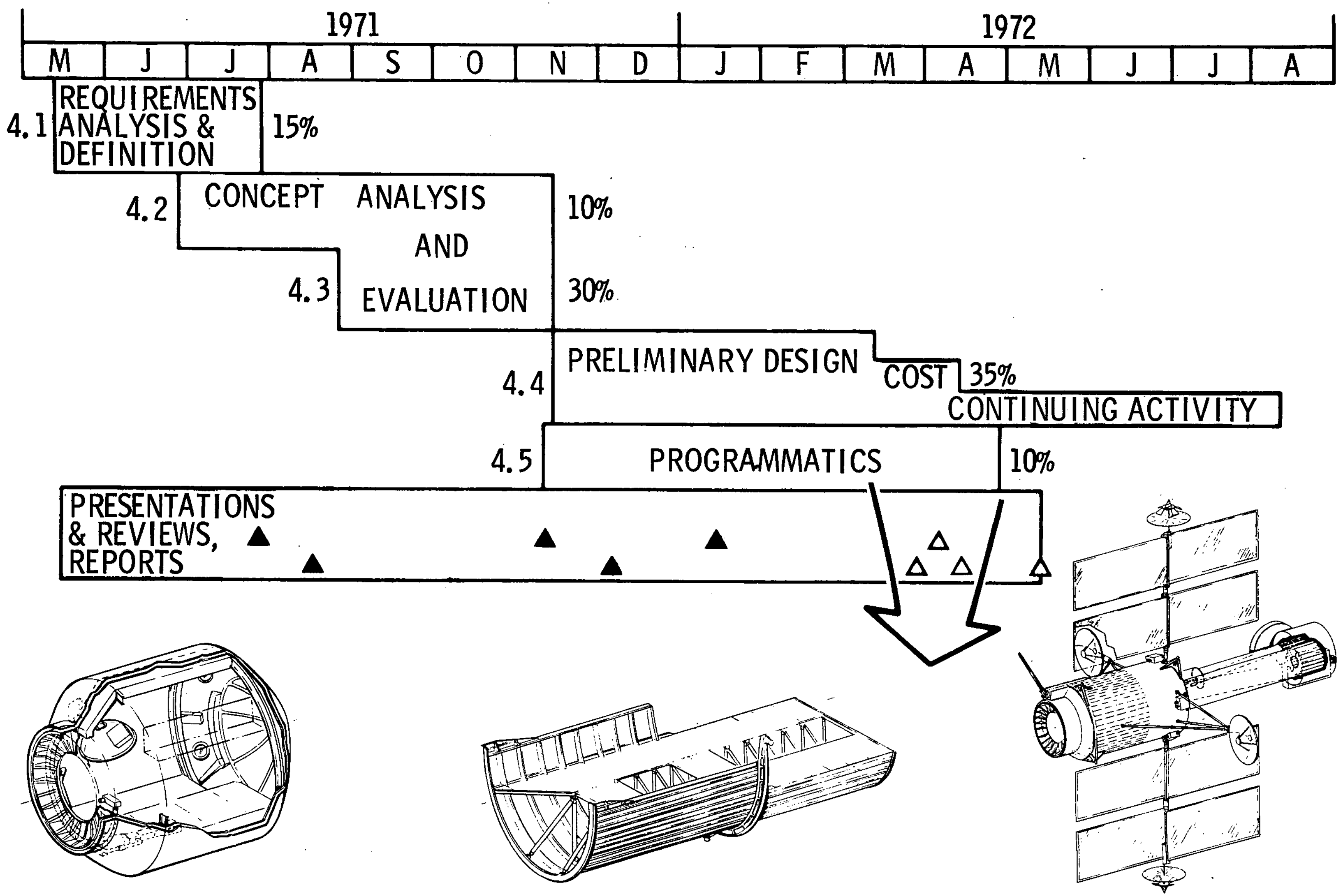
INTRODUCTION	W. WITHEE
PRESSURIZED & UNPRESSURIZED RAMs	
DESIGN	D. POWELL
OPERATIONS	A. RYAN
FREE-FLYING RAMS DESIGN & OPERATIONS	G. KAREL
SUMMARY	W. WITHEE

The third performance review of the RAM Phase B Study occurs at the completion of the preliminary design and cost analysis of the RAM family hardware element concepts selected by NASA at the completion of Task 4.3.

Continuing activities consist of three major efforts.

1. Conceptual design of the Shuttle/RAM deployment mechanism.
2. Analysis of the consideration of using graphite/epoxy composite on the Large Space Telescope.
3. European participants' subsystem analyses.

RAM STUDY PROGRAM PLAN



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RAM PROGRAM OBJECTIVES

The basic RAM program objective is to supply the users of this orbital space system with payload carriers that provide the accommodation required to allow economical realization of practical applications of space technology.

To meet this objective, the RAM family of hardware elements must be flexible to the changing funding levels that will be provided, as well as to changes in the accommodations required as priorities shift between technological fields.

A major economical consideration is the use in the RAM system of subsystems and components designed for interfacing systems. Use of shuttle system elements is maximized. Since the deployment of the Space Station will follow the operation of the shuttle and RAM systems, attention is given to the use of the RAM program elements in providing a Modular Space Station at minimum additional development cost.

Sequential development of the hardware elements of the RAM family minimizes total development cost of the RAM system of laboratories and observatories.

International participation in the effort to realize the benefits of space technology is possible in three major ways: (1) a Research and Applications Module built by European industry for their use, delivered to the United States and carried to orbit by the shuttle; (2) European experiments installed in RAMs furnished by the United States; (3) participation by European users in the data derived from experiments in orbital space.

RAM PROGRAM OBJECTIVES

- SCIENTIFICALLY RESPONSIVE LABS & OBSERVATORIES
  ACCESSIBLE — VERSATILE — ECONOMICAL
- PROGRAMMATICALLY FLEXIBLE RAM
  FUNDING — SCHEDULES — PRIORITIES
- COMPLEMENT & SUPPLEMENT SHUTTLE & SPACE STATION
  AVAILABLE CAPABILITY — MINIMIZE SENSITIVITY
- ECONOMICAL & COST-EFFECTIVE RAM
  COMMONALITY — SEQUENTIAL DEVELOPMENT
- FOSTER INTERNATIONAL PARTICIPATION
  RAM ELEMENTS — EXPERIMENTS — OPERATIONS

71-3287

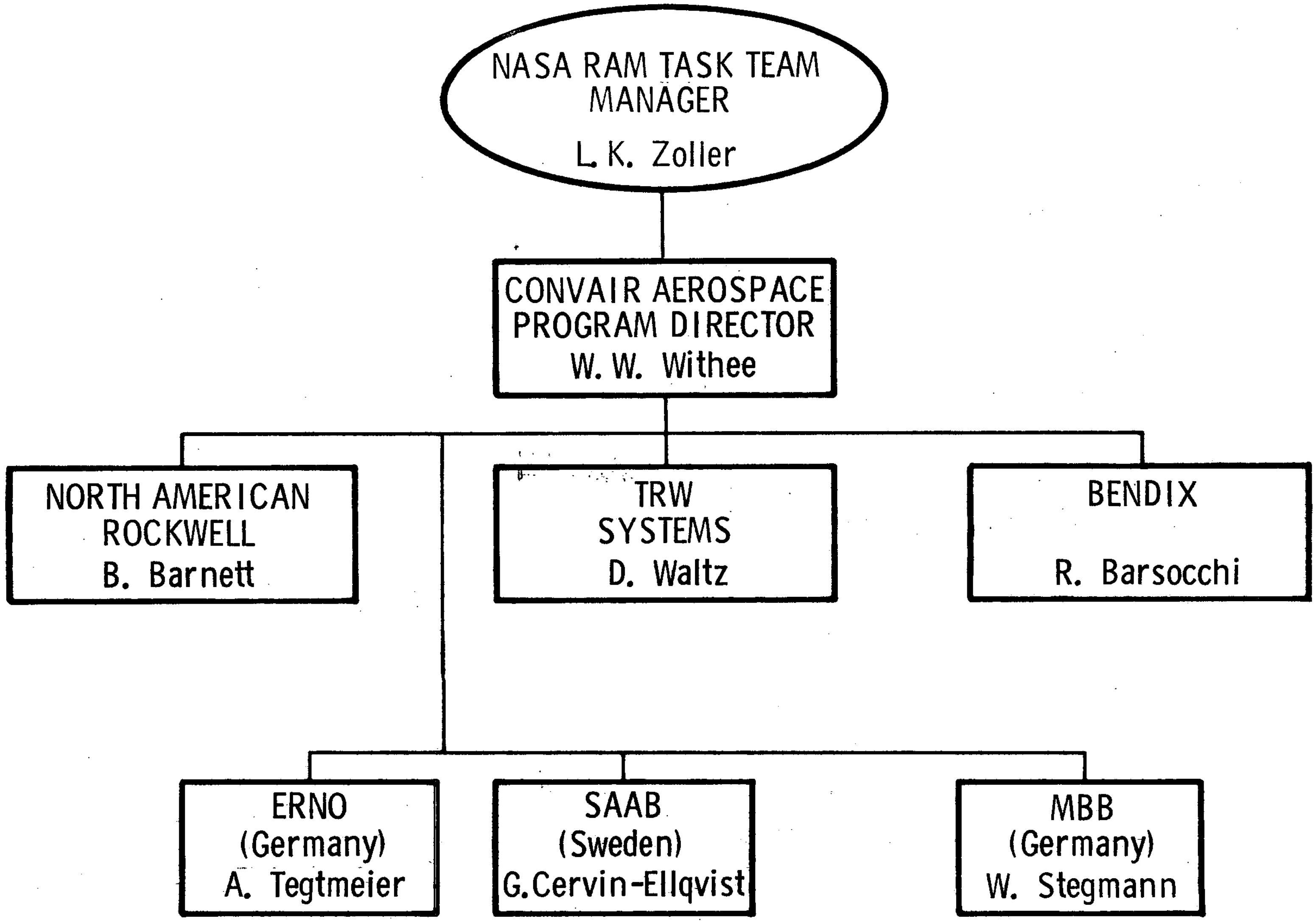
RAM STUDY TEAM RESPONSIBILITIES

The RAM Phase B study organization is a well-balanced industrial team whose experience on related space activities and scientific efforts has assured a knowledgeable treatment of the subject. The close working relations established between Bendix, North American Rockwell, TRW Systems, and Convair Aerospace have made possible a practical solution, the RAM family of hardware elements, to the diverse requirements established by the many orbital and ground systems with which this payload packaging concept must interface.

The continuous coordination of the several NASA centers and agencies involved with the NASA RAM project office has ensured that the interfacing NASA program requirements, operational and technical, were included in the concept formulation. This coordination also ensured maximum use of the applicable experience existing in NASA.

The European industry members of the team – ERNO, MBB, and SAAB – will continue to work on their system assignments to the end of the contract; however, the ease with which productive working relations have been established with their personnel to date proves the feasibility of international joint efforts in realizing the potential of useful returns from working together in orbital space.

RAM STUDY TEAM



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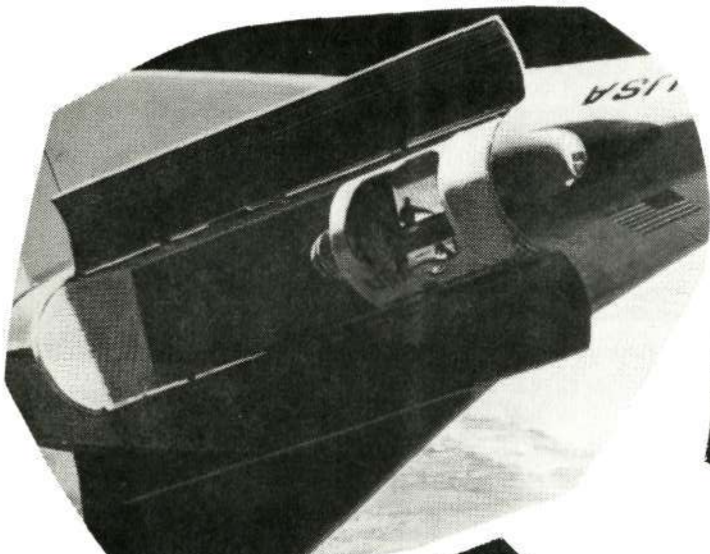
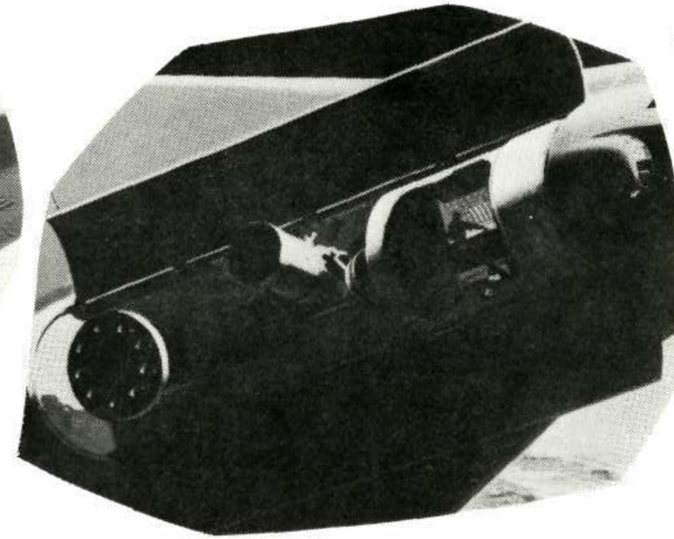
RESEARCH & APPLICATIONS MODULES (RAM)

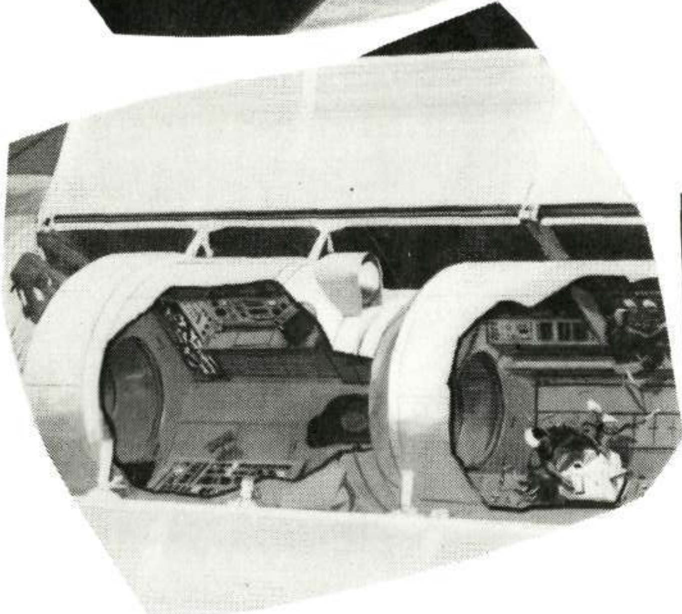
Research & Applications Modules form a family of shuttle-compatible payload carriers that provide economical experiment/payload accommodations for realization of practical applications of space technology.

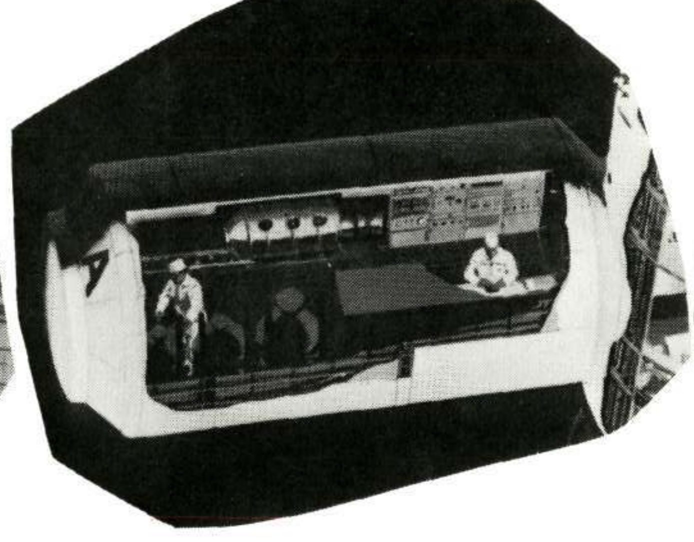
Typical of the RAM elements to be considered are the pressurized element for housing either men or equipment for sortie or station-attached operation; the pallet for mounting viewing instruments; and the free-flying RAMS to be used in advanced stellar and solar astronomy.

RESEARCH & APPLICATIONS MODULES









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EVOLUTION OF RESEARCH & APPLICATIONS MODULES

The Research & Applications Modules (RAM) family of payload carriers is envisioned as evolving from early austere sortie mission versions to more advanced sortie mission and Space Station capability, including automated free-flying RAMs serviced by the shuttle.

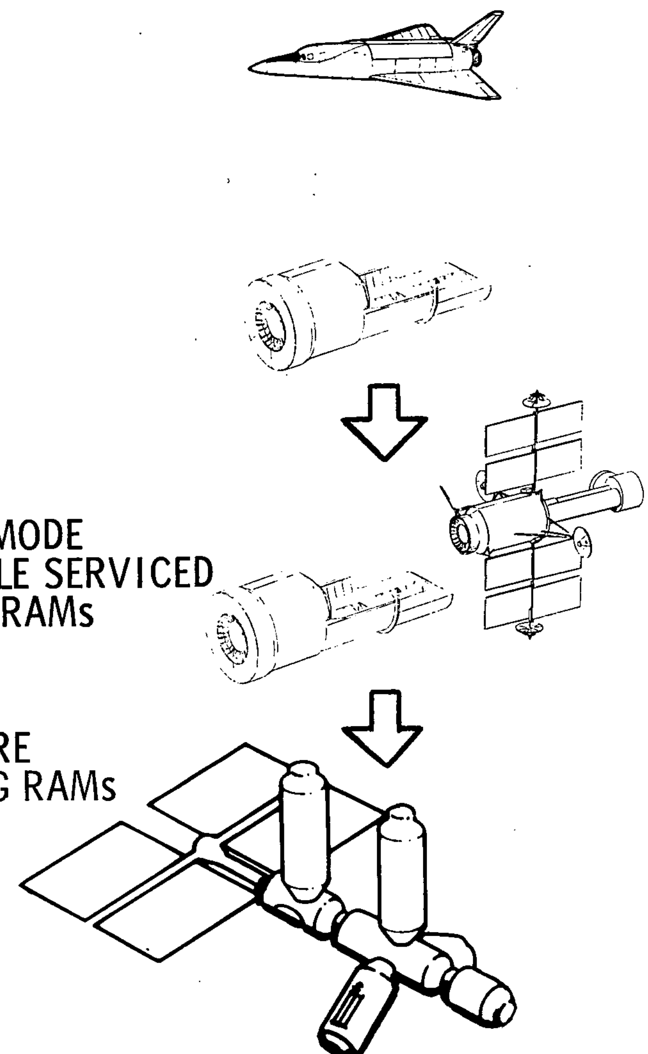
The "Sortie Can" is considered the earliest member of the RAM family to be developed, and will operate attached to the Space Shuttle on short (nominally seven days duration) sortie missions. The "Sortie Can" consists of a pressurized structure to which a pallet is attached, designed to accommodate payloads in a multiplicity of disciplines on sortie missions.

RAM will evolve from this early "Sortie Can" and will provide a more advanced capability in the sortie mission mode, as well as accommodate the large man-tended observatories in the free-flying RAM, and the more advanced labs designed to operate with the Space Station.

The Space Station mode is considered the final step in the evolution of RAM. In this mode, RAM will be attached to the core of the station to provide a long-duration mission capability for conduct of manned and man-tended applications and research programs.

RESEARCH & APPLICATIONS MODULE (RAM)

- FAMILY OF PAYLOAD CARRIERS
  - MANNED OR MAN-TENDED
  - FLEXIBLE AND ECONOMICAL
  - TRANSPORTABLE BY SHUTTLE
  - EVOLVE FROM EARLY AUSTERE TO MORE ADVANCED LABS & OBSERVATORIES
- SORTIE CAN (RAM)
  - AUSTERE, SIMPLE LAB EQUIPMENT
  - USEFUL IN A NUMBER OF DISCIPLINES
  - LEAST EXPENSIVE AND SIMPLEST RAM
- RAM (ADVANCED)
  - EVOLVES FROM SORTIE CAN WITH GROWTH CONSIDERATIONS
  - INCLUDES SHUTTLE SORTIE MISSION MODE
    FREE-FLYING RAMs, SHUTTLE SERVICED
    SPACE STATION ATTACHED RAMs
- SPACE STATION
  - FINAL STEP IN EVOLUTION OF RAM
  - RAM ATTACHES TO BASIC STATION CORE
  - STATION COULD SUPPORT FREE-FLYING RAMs



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KEY NASA RAM GUIDELINES

The Level 1 guidelines provided by NASA to the RAM Phase B Definition study, which are key to ensuring that the RAM design will accomplish its assigned role as part of the manned earth-orbital space system, are listed opposite.

These include guidelines directed at achieving a low-cost, economical applications and research capability.

KEY NASA RAM GUIDELINES

- RAM TO OPERATE IN TWO MISSION MODES:

SHUTTLE-SUPPORTED:	SORTIE FREE-FLYING
STATION-SUPPORTED:	ATTACHED FREE-FLYING

- PROGRAM STARTS WITH SHUTTLE IOC - 10-YEAR PERIOD
- BLUE BOOK IS BASIS FOR PAYLOAD SELECTIONS
- MINIMIZE EARLY-YEAR FUNDING, DEVELOPMENT COST
- COMMONALITY IS A PRIMARY GOAL

72-1740

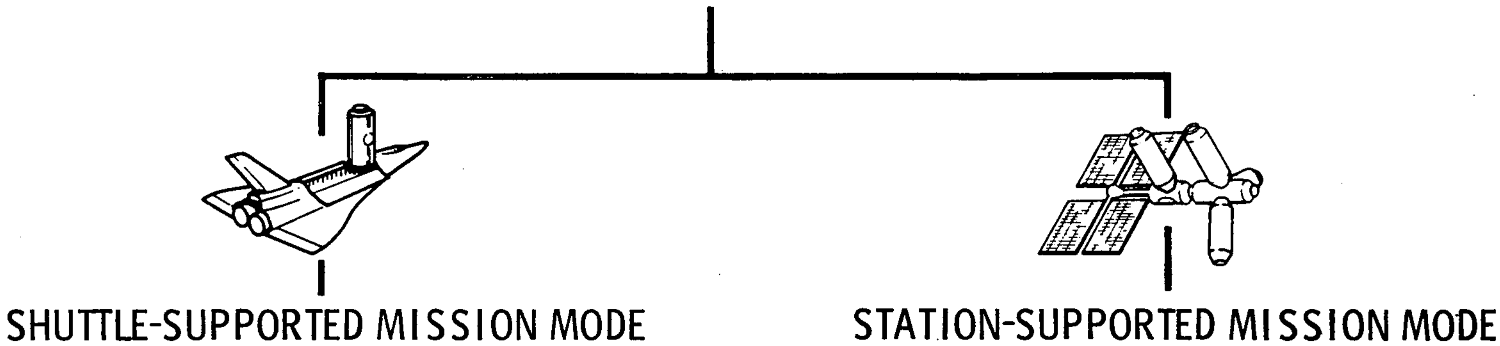
RAM MISSION MODES

RAM operates in two mission modes. Shuttle-Supported and Station-Supported.

SHUTTLE-SUPPORTED – In the shuttle-supported mode, the short-duration sortie mission, during which RAM remains attached to the orbiter for this nominal seven-day mission, offers (1) a quick turnaround for payloads and RAM hardware elements, (2) delivery capability to high-inclination orbits for global coverage, and (3) early scientific and application returns with low early-year funding. The Shuttle-Supported mode also includes the free-flying mission, where RAM is delivered to orbit by the shuttle. Following deployment and RAM checkout, the shuttle returns to earth with the free-flying RAM remaining on orbit to comduct observations over extended periods. Extreme pointing accuracies and stability are possible in this free-flying mode and a nearly contamination-free environment exists in the vicinity of RAM. Periodically (at approximately 6 to 12-month intervals) the shuttle returns to RAM to conduct manned servicing.

STATION-SUPPORTED – In the Station-Supported mode, the shuttle delivers and docks RAM to be station. The shuttle then returns to earth while the RAM remains attached to the station for on-orbit experiment operations. The Space Station provides the crew for operating and servicing RAM and the payloads. Periodic shuttle logistics flights carry expendables and replacement equipment to the station for RAM use. The free-flying mission can also be station-supported. In this mode, the shuttle delivers and docks RAM to the station. The shuttle returns to earth while the free-flying RAM is checked out, calibrated, and prepared for free flight at the station. The RAM then undocks and translates to its operational position co-orbital with the station. Periodically, the free-flying RAM rendezvous and docks with the station for manned servicing.

RESEARCH & APPLICATIONS MODULES



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RAM MISSION SCENARIO

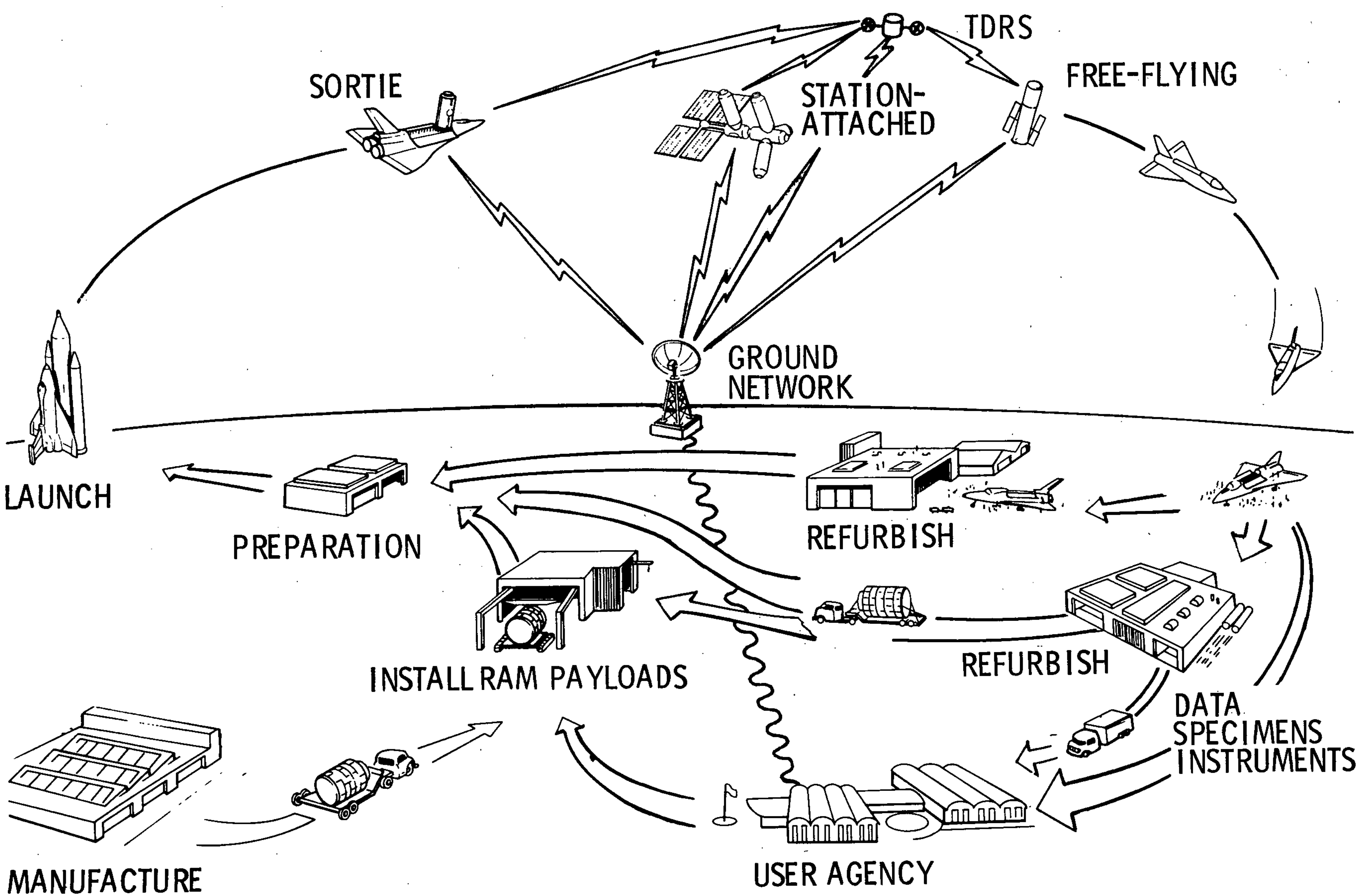
The opposite chart depicts the overall operation of RAM in its two assigned mission modes:

1. Shuttle-supported, where all operations, including sortie missions and delivery/service and retrieval of free flying RAMs, are accomplished using the Space Shuttle.

2. Station-supported, where RAM operates in conjunction with and using the resources of, the Space Station. This mode can include the support of free-flying RAMs. The shuttle in this mode provides logistic support.

Initiation of a particular mission occurs with the definition of the payload and its scheduled launch date. RAM production, payload development, and participation of the scientist/user must be scheduled so that installation of the RAM payloads and preflight preparation of instrumentation and, in some cases, test specimens, will coincide with the scheduled launch. After installation of the RAM into the orbiter, the particular RAM is boosted into orbit and is deployed/operated in one of three possible operational modes: Sortie, Station-Attached, or Free-Flying. Following deployment/operation, the shuttle returns to earth for refurbishment. In instances in which the shuttle returns a RAM to earth, it will generally be necessary to refurbish the RAM and update the payload. In instances in which the RAM payload contains stored data, experiment-peculiar instruments, and/or specimens, they must be removed, attended, and delivered to the user in a timely manner.

RAM MISSION SCENARIO



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EXPERIMENT SPECTRUM

Source of Payloads

The chart illustrates the wide range of research and applications payloads from which requirements on RAM are derived. Primary source of data on such representative payloads is "Reference Earth Orbital Research and Applications Investigations" (Blue Book) NHB 7150.1, 15 January, 1971.

This spectrum of payloads provides definition of applications and research activities in the seven disciplines shown, which covers the known range of interests in earth orbital experimentation. The range covers activities from those which hold promise for returns that have direct application to on-earth processes, to experiments and observations that will serve to expand man's scientific knowledge.

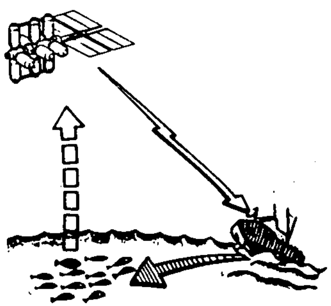
Satisfying the diverse needs of these payloads and users, requires the use of both mission modes:

1. Shuttle Supported – For global coverage and non-station orbits, as well as early returns.
2. Station Supported – For long mission times, resources, and physical sizes involved.

Other RAM characteristics effected by these diverse needs are discussed in following charts.

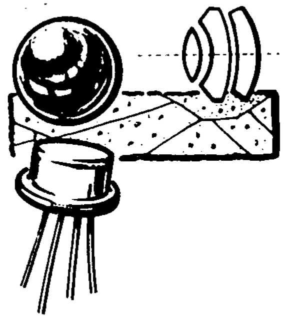
EXPERIMENT SPECTRUM
Source of Payloads

EARTH OBSERVATIONS



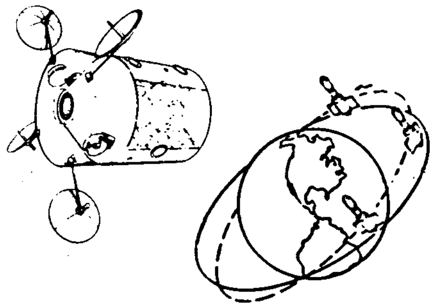
- WEATHER
- POLLUTION
- WATER
- RESOURCES

MATERIALS SCIENCE



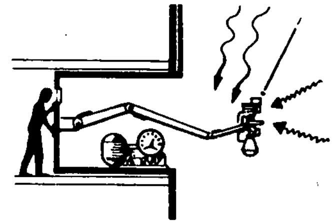
- VACCINES
- SEMICONDUCTORS
- GLASSES
- ALLOYS

COMMUNICATIONS/NAVIGATION



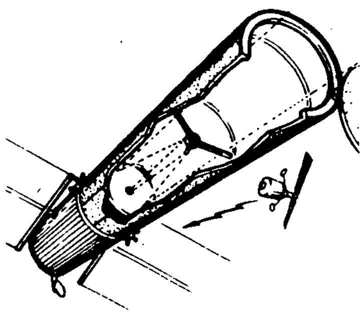
- AIRCRAFT & SHIP TRAFFIC
- RESCUE

TECHNOLOGY



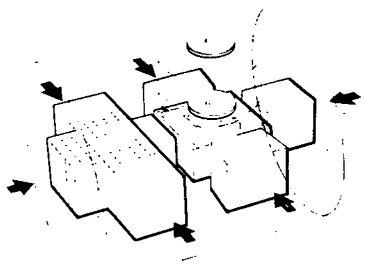
- TECHNOLOGY
- SPACE SYSTEMS

ASTRONOMY



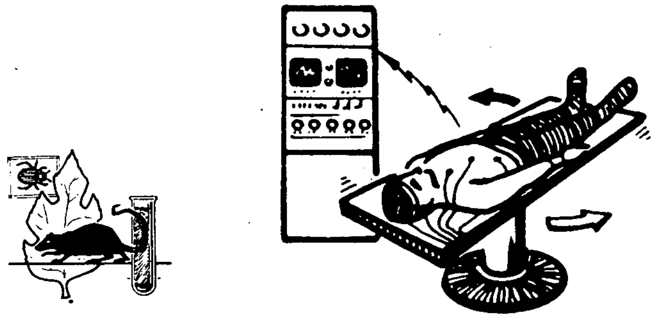
- STELLAR
- SOLAR
- X-RAY
- IR
- UV

PHYSICS



- COSMIC
- MAGNETOSPHERE
- PLASMA

LIFE SCIENCES



- MEDICAL & BIOLOGICAL RESEARCH
- LIFE PROCESSES

72-1750

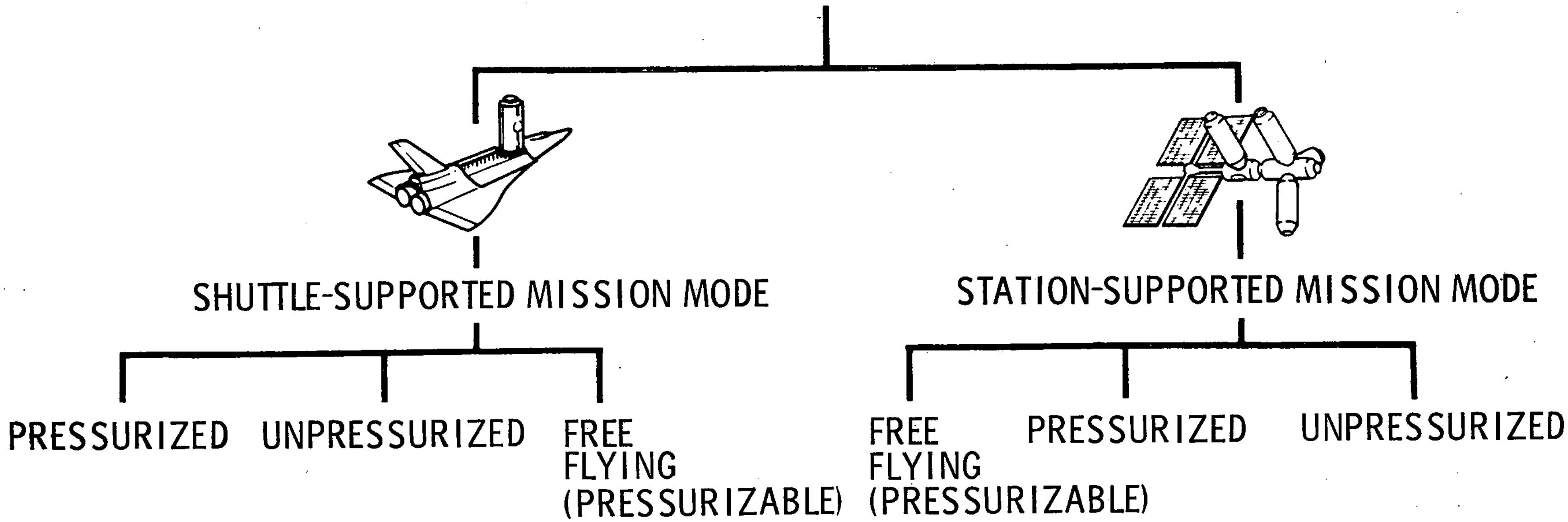
RAM USER ACCOMMODATIONS

Meeting the needs of the applications and research users of RAM requires that in each mission mode, three primary types of accommodations be provided:

1. Pressurized – Continuous shirtsleeve environment for on-orbit housing of the experimenter and his equipment.
2. Unpressurized – For mounting sensors and equipment for which their is no planned access while on orbit.
3. Free Flying (Pressurizable) – Support of large observatories in a contaminant-free environment, with capability to provide manned access to instruments at periodic intervals of 6 to 12 months.

The assignment of particular applications and research activities to these type accommodations and to the two mission modes is dependent on specific user needs for on-orbit access, and to types of orbits, orientation, and missions, as described in following two charts.

RESEARCH & APPLICATIONS MODULES



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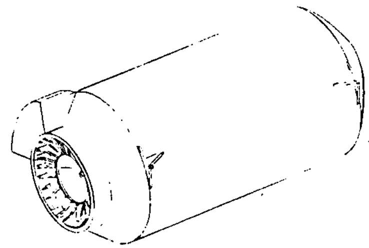
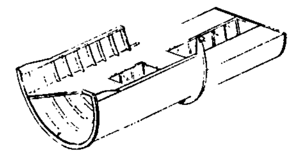
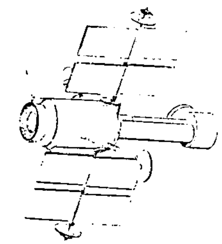
USER ACCOMMODATION REQUIREMENTS

Consideration of user needs requires that the RAM family be comprised of three types of accommodations designed to support applications and research activities:

1. Pressurized – To provide on-orbit shirtsleeve environment for either direct conduct of experiment activities within a module, or for control of sensors or other equipment exterior to the module.
2. Unpressurized – To provide mounting areas for sensors or other equipment exterior to a pressurized lab, as a means to augment the available mounting area.
3. Free Flying (pressurizable) – To provide a contaminant-free environment for the large man-tended observatories, with provisions to permit pressurizing for periodic access by man.

The opposite chart depicts these types of accommodations and indicates the general user needs within each of the applications and research disciplines.

USER ACCOMMODATION REQUIREMENTS

	TYPE OF ACCOMMODATION		
	PRESSURIZED	UNPRESSURIZED	FREE-FLYING
			
ASTRONOMY	MANNED CONTROL	SENSOR MOUNTING	CONTAMINANT-FREE PERIODIC ACCESS
PHYSICS	MAN-CONDUCTED	—	—
EARTH OBSERV.	MAN CONTROL	SENSOR MOUNTING	—
COMM/NAV.	MAN CONTROL	SENSOR MOUNTING	—
MTL. SCI. & MFG.	MAN-CONDUCTED	—	—
TECHNOLOGY	MAN-CONDUCTED	TANKS & EVA EQPT.	—
LIFE SCIENCES	MAN-CONDUCTED	—	—

72-1738

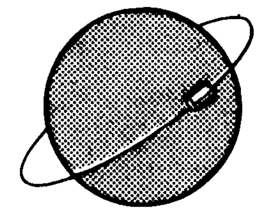
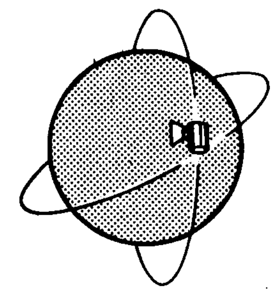
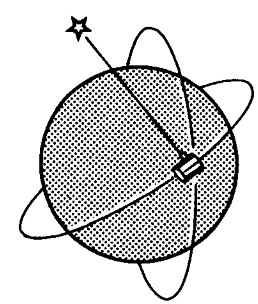
For purposes of mission planning and determination of user accommodation requirements, it is convenient to group experiment activities into three areas. Each has its own set of orbital and orientation conditions: processes in zero-g, earth measurements, and celestial observations.

PROCESSES IN ZERO-g – Materials science, life sciences, physics, chemistry, and technology disciplines are represented in these payloads. The primary payload requirement is a low-g environment. Payloads requiring long experimentation periods at low-g conditions are best accommodated in the station-attached mode. Meaningful information, however, can be obtained for a significant number of payloads over the shorter experimentation periods available in the shuttle-supported sortie mission mode. Typical objectives are the development of new processes or advancements in existing processes for possible application on earth, and the development of space processing facilities.

EARTH MEASUREMENTS – These payloads include measurements of the earth surface, atmosphere, magnetosphere, and communications experiments. Earth measurements payloads are characterized by requirements for a stable platform for short observation periods. Since global coverage is desirable, both the station-attached and sortie mission modes are applicable for these payloads, with the sortie mission providing the non-station orbits. Typical operational objectives are inventorying and forecasting earth resources for direct benefit to mankind and the advancement of communications and navigation system technologies.

CELESTIAL OBSERVATIONS – These payloads provide for observation of solar events and the investigation of stellar and interstellar target areas. Primary celestial observation requirements are a stable platform for extended observation periods with optimized viewing angles and a contamination-free environment. These payloads are well adapted to the free-flying mission mode; however, many payloads can be adequately accommodated in the sortie mission mode for early scientific return and as a precursor for observation techniques and equipment.

PAYLOAD & MISSION REQUIREMENTS

PAYLOAD INVESTIGATION AREA	TYPICAL OBJECTIVES	PRIMARY MISSION REQUIREMENTS	
PROCESSES IN ZERO-g • MATERIALS • LIFE SCIENCES • PHYSICS • CHEMISTRY • TECHNOLOGY	APPLICATION TO EARTH PROCESSES SPACE PROCESSING FACILITIES	LOW-g ENVIRONMENT LONG EXPERIMENT PERIODS	
EARTH MEASUREMENTS • SURFACE • ATMOSPHERIC • MAGNETOSPHERIC • COMMUNICATIONS	EARTH INVENTORY & FORECASTING ADVANCEMENT OF COMM/NAV SYSTEMS	STABLE PLATFORM – SHORT OBSERVATION PERIODS GLOBAL COVERAGE	
CELESTIAL OBSERVATIONS • SOLAR • STELLAR • INTERSTELLAR	SOLAR PROCESSES EXTENT & CONTENTS OF UNIVERSE ENERGY FORMS & SOURCES	STABLE PLATFORM - LONG OBSERVATION PERIODS OPTIMIZE VIEWING CONTAMINATION-FREE ENVIRONMENT	

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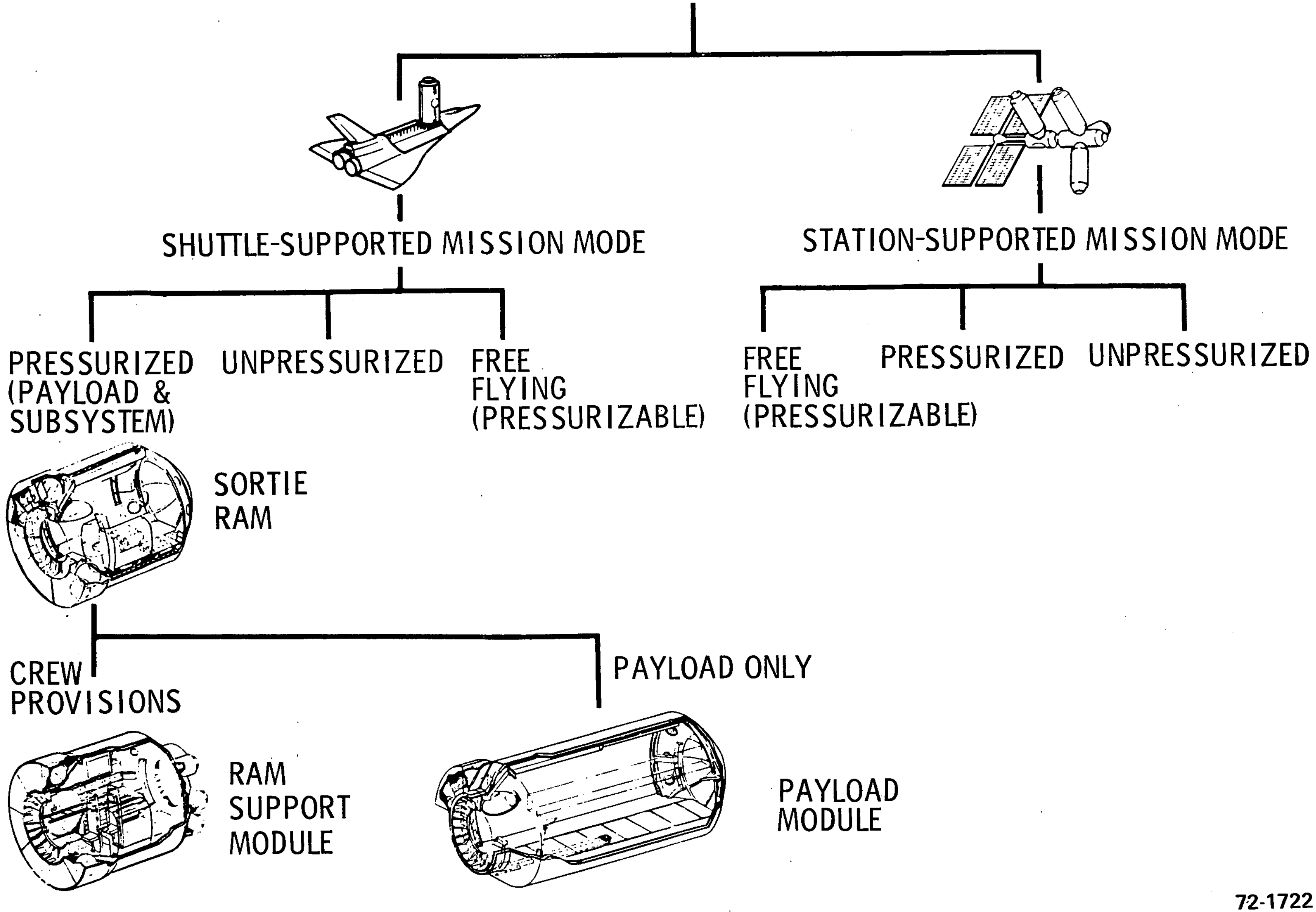
RAM CONFIGURATIONS

From the theoretical total of six elements – i.e., three types of accommodations in two mission modes – two primary factors affect the final number of configurations required.

The first factor is programmatic consideration of providing additional crew members to increase returns on the shuttle-supported sortie mission. This is accomplished as described in following chart by adapting the basic pressurized sortie mission RAM to provide crew habitability and subsystems, and a second adaptation of this unit to house only payloads that use subsystems in the crew module.

The second factor, commonality among configurations, is discussed in subsequent charts.

RESEARCH & APPLICATIONS MODULES



The shuttle-supported sortie mission mode has emerged as a most promising means to achieve an early start in the RAM program and thereby achieve early returns from applications and research efforts.

Returns that can be realized from a single mission are largely proportional to the number of experimenters that are present on-orbit. The basic experiment crew size has been set at two experiment specialists, to coincide with the number that can be supported on-orbit by the orbiter resources and habitability provisions (in the orbiter baselined for the RAM study).

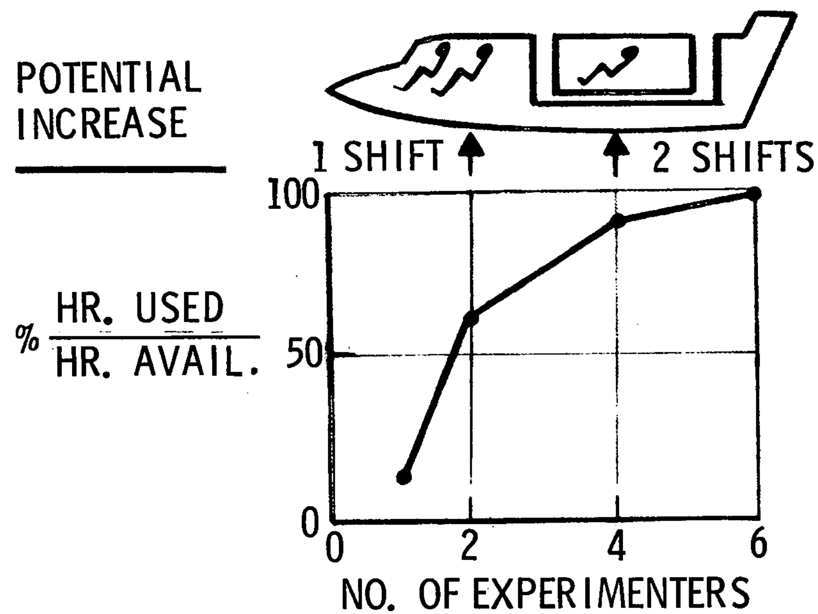
An analysis of the on-orbit payload activities was made using various sizes of experiment specialist crews for the representative sortie mission payloads. The result of this crew sizing analyses is shown on the chart. Its intended use is to show the relative value of increased crew sizes for RAM concepts. The percentage of used hours to available hours shown is simply crew experiment hours accomplished, compared to the possible number of crew experiment hours defined by timelines for the representative payloads. Crew hours accomplished with a given crew size were determined through examination of the skills and the total number of hours required to accomplish the experiments, as defined by the timelines.

The graph shows that a significant increase in returns in achieved by adding two men and going to a two-shift operation, i.e., an experiment crew of four working two shifts results in a 60% increase in percentage of hours used to hours available over a crew of two operating on one shift. (The average gain in payload utilization is minor when crew size is increased beyond four.)

To provide this capability to increase the returns from these sortie missions, should this become programmatically desirable, the capability has been provided in RAM to support additional experimenters housed within RAM. This capability is provided by an adaptation of the sortie mission pressurized RAM whereby crew habitablity provisions are installed in a module in lieu of the payload. Once this is accomplished, the pressurized RAMs used to house payloads on these missions would use the subsystems provided by this RAM support module, and thus accommodate only the payload.

RAM PROGRAMMATIC CONSIDERATIONS

- AVAILABLE OPTION - INCREASE RETURNS PER SORTIE MISSIONS

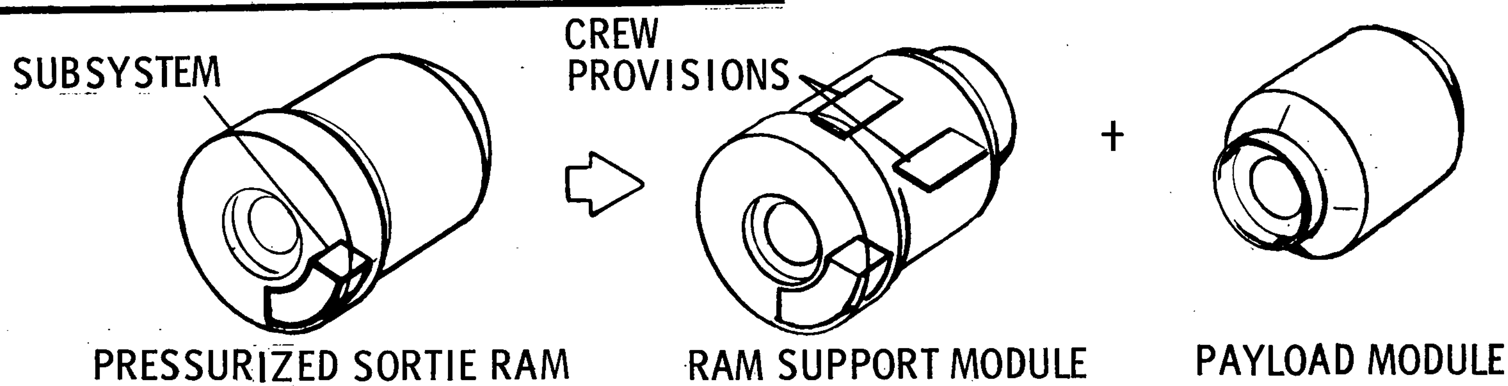


REQUIRED EXPERIMENT CREW PROVISIONS

2 EXPERIMENTERS IN SHUTTLE

> 2 EXPERIMENTERS IN RAM

- OPTION FOR INCREASED RETURNS PROVIDED BY:



72-1748

REPRESENTATIVE RAM PAYLOADS

To provide a basis for design of the RAM family of payload carriers, a representative set of experiment groupings was slected in Task 4.1. This set was selected to cover the spectrum of research and application areas of interest to a wide range of disciplines. These experiment groupings have been formed into and defined as the payloads to guide the design and operations analysis of RAM.

Although the primary source of experiment definitions has been the Blue Book, they have been further defined and supplemented by a number of related activities, including the MFSC Shuttle Payload Planning Activity, which has defined Blue Book and earlier experiments into payloads specifically tailored to shuttle-supported operations.

The payloads are divided into three categories of missions:

SORTIE MISSION – Payloads that minimize early-year funding, are compatible with the shuttle environment, and can produce meaningful scientific benefits during on-orbit missions of up to seven days.

ATTACHED TO STATION – Payloads that require manned attention while operational and are compatible with the station-induced environment and house experiments conducted over extended (three to five years) periods. The space station provides the crew and necessary subsystems support during operations.

FREE FLYING – Payloads that are unmanned while in operation because of experiment sensitivity to the Space Shuttle and Space Station-induced environments. They require infrequent servicing by man at approximately six to twelve-month intervals and can be returned to ground by the Space Shuttle for refurbishment as required.

REPRESENTATIVE RAM PAYLOADS

	NUMBER OF PAYLOADS BY MISSION TYPE		
	SORTIE MISSION	STATION-ATTACHED	FREE-FLYING
SELECTION CRITERIA ⇨	•LOW EARLY-YEAR FUNDING •EARLY RETURNS •SHORT MISSION DURATION •NONSTATION ORBITS	• LONG MISSION TIMES • STATION RESOURCES AVAILABLE	• ENVIRONMENTAL SENSITIVITY • LONG MISSION TIMES • INFREQUENT MANNING
TYPES OF PAYLOADS ⇨	MANNED LABS EARLY AUSTERE & PRECURSOR VERSIONS OPTIONAL ADVANCED VERSIONS FOR LATER MISSIONS	MANNED LABS ADVANCED VERSIONS EVOLVING FROM SORTIE LABS FULLY USE TIME & RESOURCES AVAILABLE	MAN-TENDED OBSER-VATORIES LONG-TERM EXPOSURE & STORAGE EXPERIMENTS
ASTRONOMY	8	2*	4
PHYSICS	5	2	
EARTH OBSERV.	6	2	
COMM./NAV.	3	2	
MTL. SCIENCE & MFG.	4	1	
TECHNOLOGY	8	2	2
LIFE SCIENCES	3	2	
TOTAL PAYLOADS	37	11 + 2*	6
	54 + 2*		

*ADDED DURING TASK 4.3

MAJOR COMMONALITY RAM CONFIGURATIONS

The total number of configurations necessary to accomplish the RAM missions has been minimized by taking advantage of commonality potential between RAMs used in the two mission modes: shuttle-supported and station-supported.

The approach is based on current NASA planning to have Space Shuttle IOC precede Space Station IOC. RAMs would be provided to meet the shuttle-supported program requirements, with the capability to retrofit these to the extent required to permit operation with the Space Station. This can be accomplished by relatively minor modification to the shuttle-supported RAM configurations, thus allowing a basic configuration that can be operated in either mode.

This consideration applies to three items: the sortie RAM, payload module, and the free-flying RAM. The pallet and the RAM support module are used only for sortie missions with no application to the station mode.

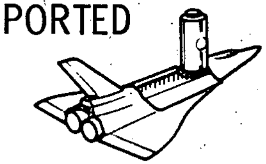
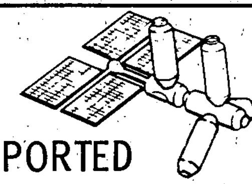
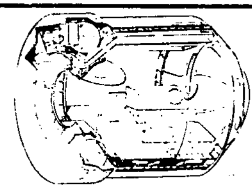
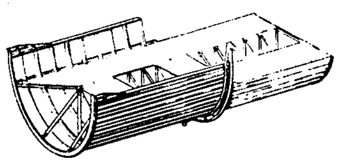
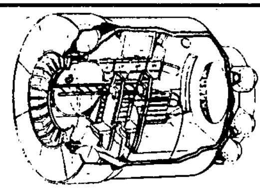
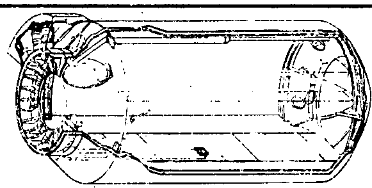
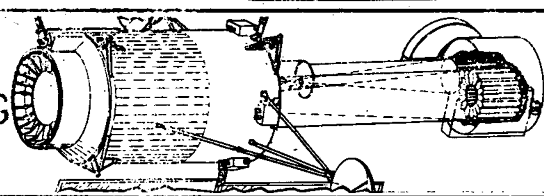
The sortie RAM can be transferred to station operation after deletion or de-activation of supporting subsystems (power, EC/LS, etc.) and provision of station interconnects, since these resources are provided by the station.

The payload module requires that a thermal fluid circulation system (provided by the RSM in the sortie mission) be provided to allow RAM independent heat rejection as required by station design.

The free-flying RAM requires revision to Comm/Data for transmission to station in lieu of TDRS link; and installation of velocity control and propulsion necessary for RAM to accomplish rendezvous and docking with the Space Station. The latter is necessary since the orbiter is the active member in the free-flying RAM service mission.

This results in a total of five RAM configurations which, with modification as applicable, meet the user needs in both Space Shuttle and Space Station-supported mission modes.

MAJOR COMMONALITY IN RAM CONFIGURATIONS

RAM CONFIGURATION	COMMONALITY BY MISSION MODE	
	SHUTTLE-SUPPORTED 	 STATION-SUPPORTED
SORTIE RAM 	BASIC	USAGE POSSIBLE - • REMOVE SUBSYSTEMS • MODIFY INTERFACE
PALLET 	BASIC	(NOT USED)
RSM 	BASIC	(NOT USED)
PAYLOAD MODULE 	BASIC	COMMON EXCEPT: • ADD THERMAL CONTROL CIRCULATION SYSTEM
FREE FLYING RAM 	BASIC	COMMON EXCEPT: • ADD DOCKING PROPULSION • DELETE COMM TO TDRS

72-1747

In summary of the foregoing, RAM is a family of manned or man-tended payload carriers that provide flexible and economical accommodations, and are transportable to and from orbit by the Space Shuttle. RAM will evolve in capability from early austere versions operating with the Space Shuttle during short-duration sortie missions, to more advanced capabilities operating in this sortie mode, and will finally evolve to advanced labs operating attached to an orbiting Space Station; this evolution will include providing for man-tended observatories.

RAM, then operates in the two-mission mode shown on the chart; Shuttle-supported, and Space Station-Supported.

To meet the needs of the user, RAM includes (1) pressurized elements for the manned labs, (2) unpressurized elements to provide additional mounting area for sensors, and (3) free-flying pressurizable elements for the man-tended observatories. These elements are provided in both shuttle-supported and station-supported mission modes.

Additionally, in the shuttle-supported mission mode. a version of the pressurized element provides a means to increase the returns on each sortie missions, by providing for support of additional experiment crew beyond that provided for in the orbiter. This crew support version can then be used in conjunction with a configuration that houses only the payload.

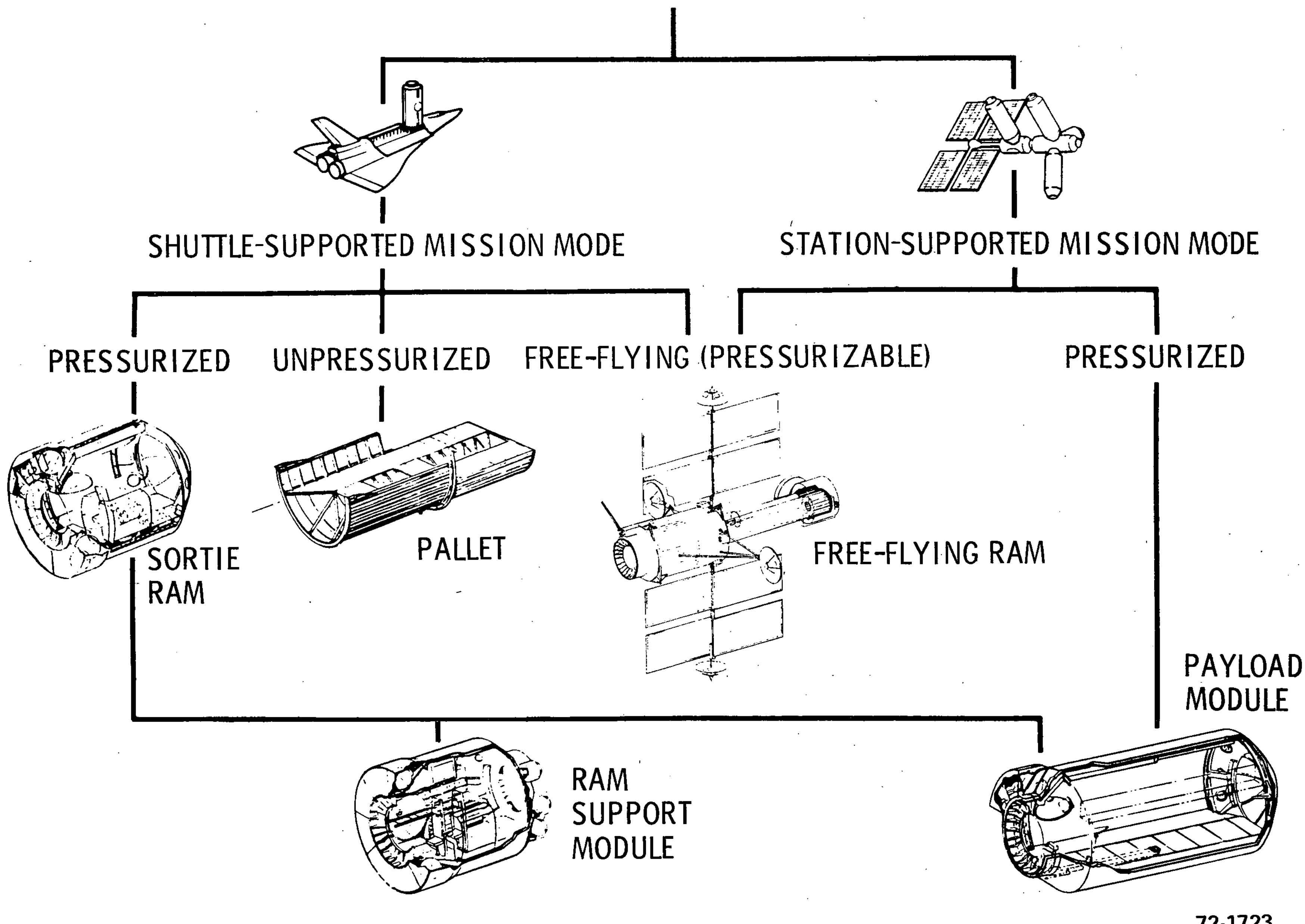
In the station mode, the unpressurized element is provided by experiment-peculiar structure, thus no basic RAM element exists for this function.

A narrowing of the potential seven resulting configurations is possible by virtue of commonality that exists between the RAM requirements for the two mission modes. The free-flying RAM is basically the same item for these modes and the same holds true for the payload module; i.e., one configuration for the two modes.

Therefore, the resultant number of configurations of RAM necessary to accommodate the representative RAM payloads operating in these two mission modes is five:

Sortie RAM
Pallet
RAM Support Module
Payload Module
Free-Flying RAM

RESEARCH & APPLICATIONS MODULES



PRESSURIZED & UNPRESSURIZED RAMs – DESIGN

D.J. Powell

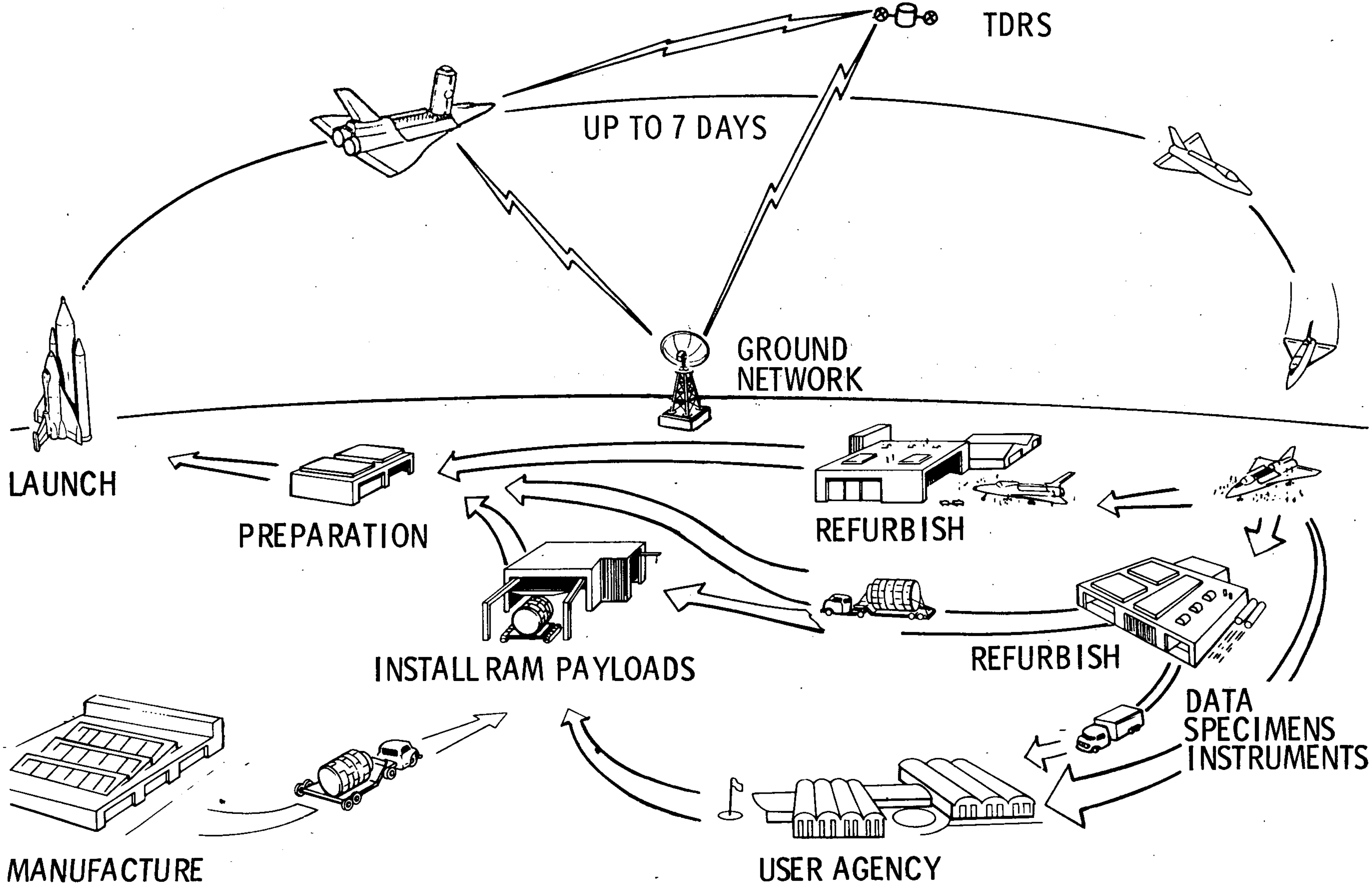
- REQUIREMENTS
- CONFIGURATIONS
- SUBSYSTEMS
- CAPABILITIES
- INTERFACES

72-1806

RAM SORTIE MISSIONS

Pressurized and unpressurized RAMs can be used for sortie missions with the shuttle orbiter. Mission duration is nominally seven days, of which five are available for on-orbit experimentation, with the possibility of extension to 30 days for experiment groups requiring it, such as certain aspects of life sciences. The needs of the RAM elements assigned to support sortie missions are; to contain adequate resources in conjunction with the shuttle capability itself, to house a variety of experiment payloads with basic RAM configurations, and to provide for ease of installation and servicing from the point of view of all users. Pressurized and unpressurized (pallet) RAMs can be used in combinations to accommodate widely varying experiment groups. The mission profile is in each case similar.

RAM SORTIE MISSIONS



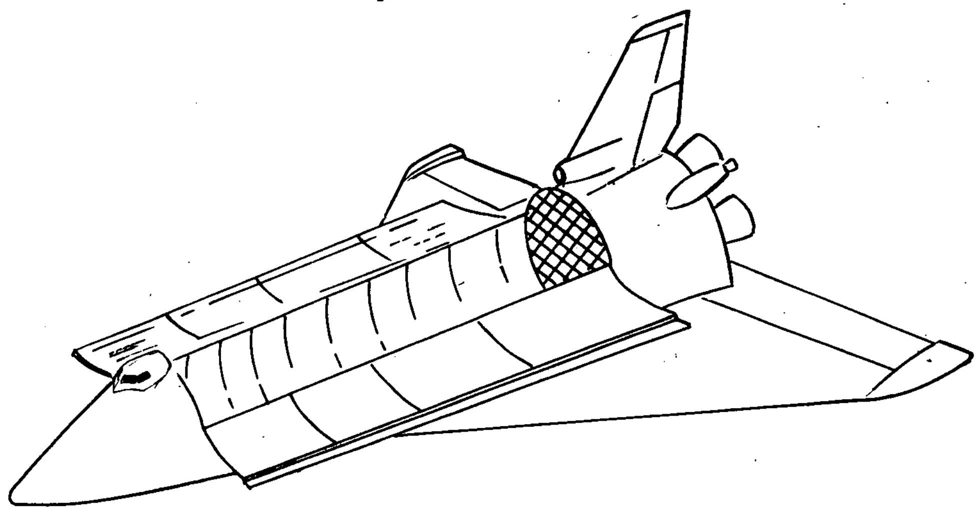
72-1690

REFERENCE SHUTTLE – PHYSICAL

Several significant physical interface characteristics of the RAM reference Space Shuttle are shown. The bases for these interface definitions were the Space Shuttle Study contractors' (North American Rockwell and McDonnell Douglas) Phase B and Phase B' reports, and data obtained from NASA-MSC amd MSFC. Other shuttle interface characteristics, not shown, of particular importance to RAM design and operations include:

1. Orbiter flight crewmen will not support normal RAM operations: however, assistance by one orbiter crewman to observe experiment EVA activities has been assumed to permit such operations in a limited number of cases when only two payload specialists are carried.
2. Weight of the two RAM payload specialists and their personnel provisions housed in the orbiter vehicle is chargeable to orbiter vehicle.

REFERENCE SHUTTLE
Physical



CHARACTERISTIC	INTERFACE
PAYLOAD BAY SIZE	15-FT. DIA. x 60-FT. LENGTH (MAX. RAM SIZE 14 x 58 FT.)
PAYLOAD DEPLOYMENT	MANIPULATOR OR HINGED DEPLOYMENT MECHANISM
ENTRY CG CONTROL	20K P/L - 12 TO 59 FT. AFT OF INTERFACE 32K P/L - 17 TO 48 FT. AFT OF INTERFACE
CREW COMPLEMENT	TWO PILOTS + TWO EXPERIMENT/MISSION SPECIALISTS
CREW PROVISIONS	28 MAN-DAYS CONSUMABLES (FACILITIES DESIGNED FOR 42 MAN-DAYS CAPACITY)
CREW HABITABILITY	NOT COMPARTMENTALIZED
AIRLOCK	ADJACENT TO PAYLOAD BAY & PROVIDES ACCESS TO & REFUGE FOR PAYLOAD
PAYLOAD CONSOLE	MISSION SPECIALIST C&D FOR PAYLOAD MONITORING/CHECKOUT/CONTROL/COMMUNICATION

72-1685

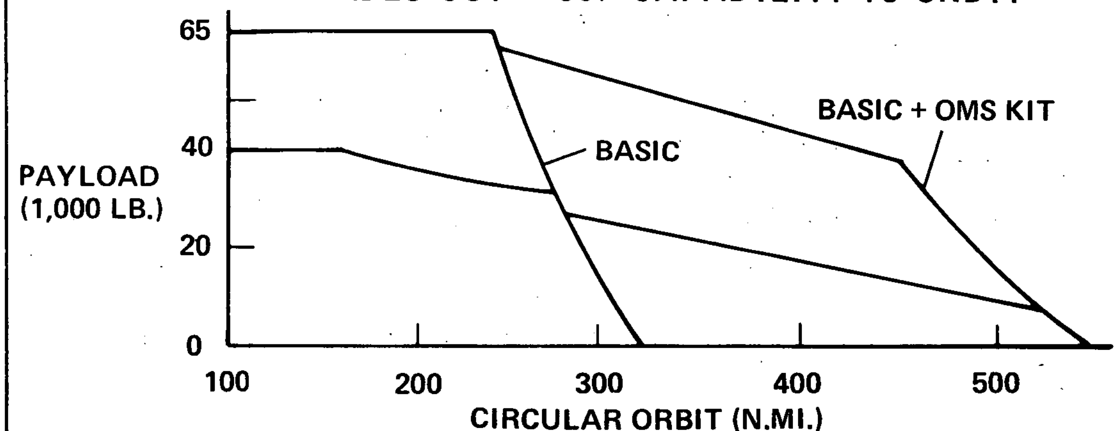
REFERENCE SHUTTLE PERFORMANCE

Several significant performance interface characteristics of RAM reference Space Shuttle are shown. The payload to orbit altitude capability shown assumed that the Shuttle's main propulsion subsystem injected the orbiter vehicle into a 50 x 100-n.mi. orbit and the OMS performed the circularization at 100 n.mi. followed by a coplanar orbital transfer to a higher altitude and the deorbit maneuver. The two limiting payload to orbit curves shown in the chart represent the capability of the basic OMS which is an integral part of orbiter vehicle, and the OMS kit which can be added to orbiter vehicle to increase the orbital altitude capability. Both the basic OMS and the OMS kit have 1,000-fps velocity increment capability, but the OMS kit volume and weight are chargeable to payload. The two Shuttle Level 1 guidelines represented in the chart are;

1. Shuttle will be launched due east and requires a payload of 65,000 lb. with the orbiter vehicle airbreathing engines removed. For this mission orbiter vehicle on-orbit translational velocity requirements are 1,000 fps from the orbital maneuver subsystem (OMS) and 120 fps from the RCS.
2. Shuttle will be launched into a polar orbit and requires a payload capability of 40,000 lb., with the orbiter vehicle airbreathing engines removed. For this mission orbiter vehicle on-orbit translational velocity requirements are 650 fps from the orbital maneuver subsystem and 120 fps from the RCS.

Total allowable launch weight of RAMs on a single shuttle is not to exceed 80% of shuttle payload to orbit performance capability, as represented by the payload/orbital altitude curve presented on the chart.

REFERENCE SHUTTLE
Performance

CHARACTERISTICS	INTERFACE
PERFORMANCE TO ORBIT PAYLOAD/ORBIT CAPABILITY BASIC OMS OF 1,000 FPS OMS KIT OF 1,000 FPS	ABES OUT — 80% CAPABILITY TO ORBIT 
LANDING WEIGHT	40,000 LB. FULL SAFETY FACTOR
POINTING/STABILITY	±0.5°/±0.03 DEG./SEC., ALL-AXIS
ELECTRICAL POWER	28 VDC/1,000 W AVG./50 KWH TOTAL ENERGY
COMMUNICATION	VOICE: S-BAND/MSFN & VHF/TDRS DATA: S-BAND/MSFN: 1 MBPS VHF / TDRS; 10 KBPS GRD TRACKING: S-BAND/MSFN RENDEZVOUS RANGING: VHF
CONTAMINATION SOURCES	ACPS, CABIN LEAKAGE & OUTGASSING

72-1679

DRIVING PAYLOAD REQUIREMENTS

The spectrum of driving payload requirements for the sortie RAM mission is summarized according to payload disciplines. Maximum values are shown where applicable. Areas of particular RAM configuration significance are:

1. Large area for external mounting of gimbaled telescopes and arrays which characterize the representative astronomy payloads.
2. Versatile space/mounting provisions necessary to accommodate the range of scientific airlocks used in the Physics and Technology disciplines.
3. Capability for on-orbit instrument access in a pressurized area for external viewing sensors in earth observations and communication/navigation.
4. Crew size or equipment volume requirements typical of representative life sciences payloads.

DRIVING PAYLOAD REQUIREMENTS

ASTRONOMY	PHYSICS	EARTH OBSERVATIONS
• POINTING ACC.: 1.0 ARC-SEC. STAB.: 0.5 ARC-SEC./OBS. DURATION: 5.0 HR. • LOW CONTAMINATION • EXT. MTG.: 9,300 LB. 250 $FT.^2$	• SCI. AIRLOCKS: 42 D x 132 IN. • EQUIP. WT.: 13,400 LB. • BOOMS LENGTH-160 FT. (MAX.) NUMBER - 3 • SUBSATELLITE CONTROL	• DATA RATE: 51.4 MPS • AVG POWER: 4.8 KW • SENSOR SWEEP: ±60° • SENSOR DEPLOYMENT • SENSOR ACCESS - PRES.
COMM/NAV	MATERIALS SCI./TECHNOLOGY	LIFE SCIENCES
• SENSOR DEPLOYMENT • SENSOR SWEEP: ±90° • SCI. AIRLOCKS: 42 D x 72 IN. • SUBSATELLITE MTG. • INSTRUMENT ACCESS - PRES.	• PEAK POWER: 30 KW • CRYOGENIC FILL & VENT • TELEOP. AIRLOCK: 68 D x 72 IN. • LOCAL FOV - SPHERICAL • DATA STORAGE: 35 REELS	• PRES. EQUIP. VOL: 1,250 $FT.^3$ • TIME-CRITICAL SPECIMEN LOADING • CREW SIZE: 6 • >7-DAY MISSION

72-1745

DESIGN REQUIREMENTS SUMMARY
RAM Payloads

Design requirements for sortie mission payloads are summarized according to three basic payload types: processes in zero-g (zero-g labs), earth measurements, and celestial observations. The maximum (design) value from the range of representative payload requirements is shown for each payload type.

Zero-g payloads set the maximum requirements for payload crew size and for pressurized equipment volume (and weight). The volume shown is for the equipment and does not include manned access requirements. RAM payload data rates and average power requirements are driven by the Earth Measurements payloads. Zero-g labs have no viewing requirements except for local observations of on-orbit operations such as EVA. Earth measurements and celestial observations payloads set the viewing requirements with the accuracy and duration of the celestial observations being the most demanding during sortie missions.

DESIGN REQUIREMENTS SUMMARY
RAM Payloads

PAYLOAD TYPE	REQUIREMENTS					
	EQUIPMENT PRESSURE VOL. (FT.^{3})	EXPERI-MENT WT. (LB.)	CREW SIZE	VIEWING	AVG. POWER ON (KW)	MAX. DATA RATE (MPBS)
ZERO-g LABORATORY	1,250	13,400	2 - 6	NONE/ LOCAL	3.3	0.1
EARTH MEASUREMENT	125	4,800	2 - 4	EARTH	4.8	51.4
CELESTIAL OBSERVATION	270	12,400	2 - 4	STELLAR/ SOLAR	1.3	1,200

72-1744 R

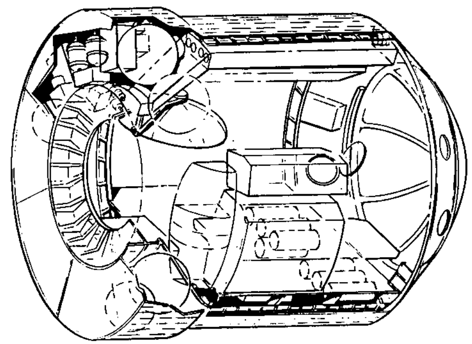
RAM SORTIE MISSION HARDWARE

The hardware shown, in combinations listed below, is used for the various RAM sortie missions.

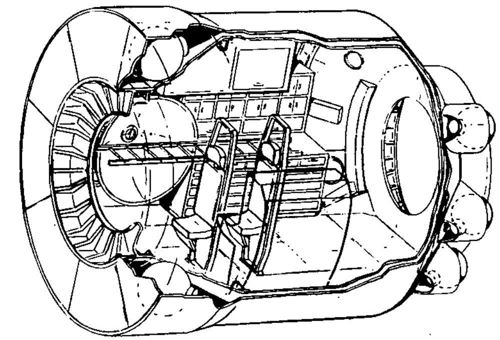
1. Sortie RAM
2. Sortie RAM/Pallet
3. RAM Support Module/18-foot Payload Module
4. RAM Support Module/18-foot Payload Module/Pallet
5. RAM Support Module/32-foot Payload Module

The RSM is always used with a payload module. The pallet is attached to either a sortie RAM or an 18-foot payload module.

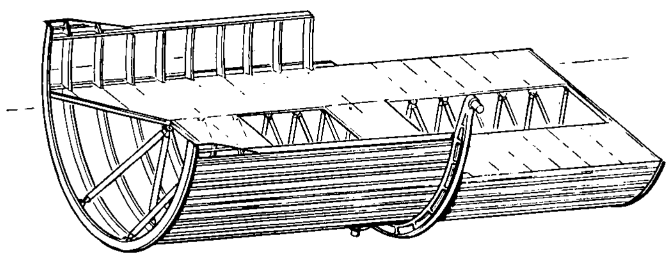
RAM SORTIE MISSION HARDWARE



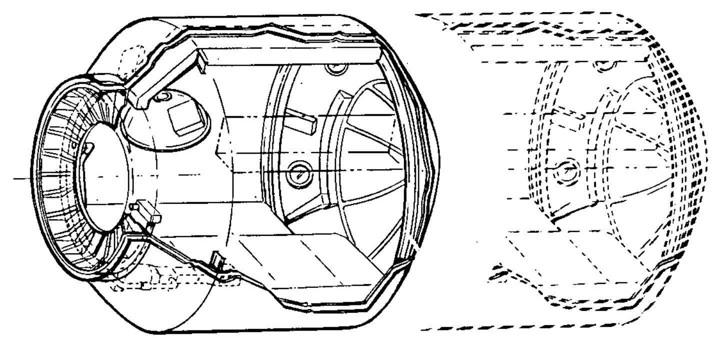
SORTIE RAM



RAM SUPPORT MODULE



RAM PALLET



RAM PAYLOAD MODULE
(18-FT. & 32-FT.)

72-1680

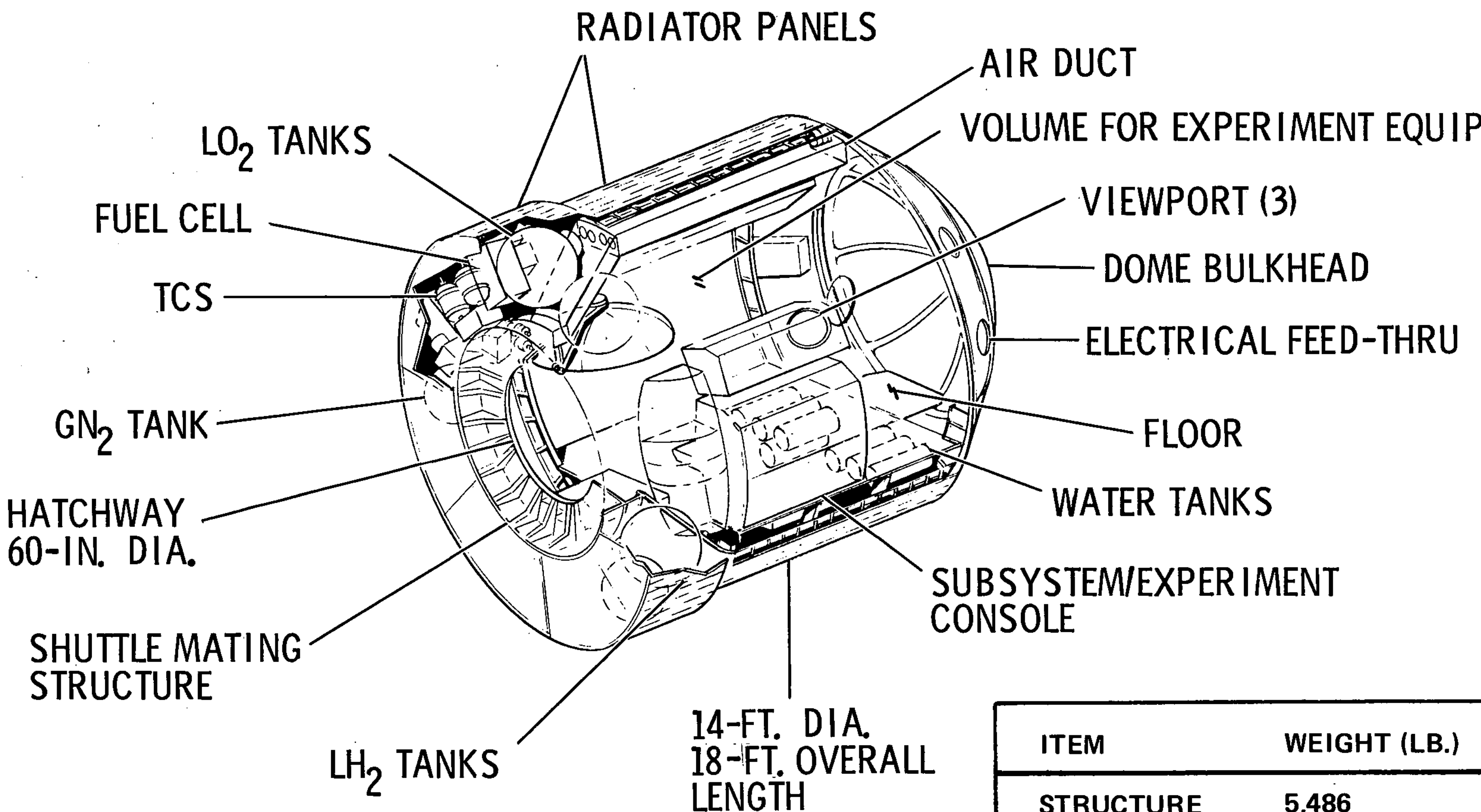
SORTIE RAM
General Arrangement

The sortie RAM, operated by two payload specialists, is designed to accommodate a signficant range of experiment payloads. The interior above-floor arrangement consists primarily of a control and display console for subsystems and experiments, and provisions for easy installation and removal of experiment equipment peculiar to each payload. The integrated control and display console is located at the forward end relative to the orbiter with the experiments aft. Subsystem components and assemblies mounted within the pressurized volume are located at the module forward end and beneath the floor. Subsequent charts give details. The internal arrangement is designed for ease of crew movement and access to equipment.

A forward external equipment bay, covered with a circumferential 3-ft. wide radiator extends aft from the orbiter interface plane. Diameter across the radiator is 15.0-feet, which is a maximum envelope allowed in the cargo bay of the orbiter. Located in the equipment bay are two LO_2 tanks, three LH_2 tanks, two N_2 tanks, a single fuel cell, fuel cell ancillary equipment, thermal control subsystem assemblies and a ground disconnect panel for ground services. The forward conical transition section is pierced four places with feedthroughs for fuel cell cabling and external control and monitor circuits, water plumbing, gaseous O_2 and N_2 and the cabin atmosphere relief and vent valve.

A removable 102-inch diameter aft domed bulkhead can be replaced by special experiment integration equipment bulkheads capable of supporting internal viewing instruments and large external experiment sensors. Alternatively, the removable bulkhead may be replaced by a docking structure and mechanism for servicing the Free-Flying RAM.

SORTIE RAM
General Arrangement



ITEM	WEIGHT (LB.)
STRUCTURE	5,486
SUBSYSTEMS	4,730
DRY WEIGHT	10,216

72-1670

SORTIE RAM STRUCTURE

The sortie RAM structure provides support for the experiments and subsystems and containment of a livable atmosphere so that experiments may be performed and equipment maintained within a shirtsleeve environment. The structure must hold internal pressure and react external forces due to boost and maneuvering loads imposed by the orbiter and by docking procedures.

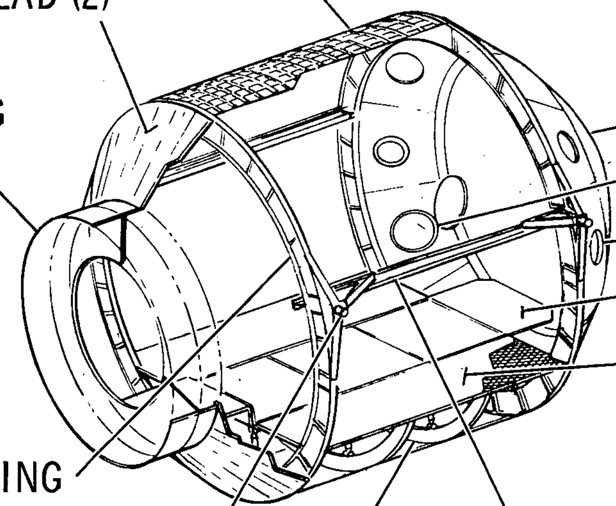
The structure is made up of the pressure shell, which consists of cylindrical walls, bulkhead, closures and docking adapter. It also consists of the environmental protection system, the RAM/orbiter support system and secondary structure that includes internal floors, internal and external equipment supports.

The structure is basically a cylindrical shell with conical bulkheads. It has a maximum internal diameter of 160 inches and a diameter over the cylindrical section of 14 feet. The maximum diameter of the module is 15 feet (over the forward radiator). The total internal volume is 1,950 cubic feet.

SORTIE RAM STRUCTURE

MATERIAL NOTES

WELDED PRESSURE SHELL 2219-T851 Al
SECONDARY STRUCTURE 2024-T3 Al
RAM ORBITER FITTINGS 4340 STEEL



ITEM	WEIGHT (LB)
PRESSURE SHELL	755
BULKHEADS	1,197
REINFORCING ATTACH. MEMBERS	969
ORBITER ATTACH. & BACKUP	673
FLOORS	361
BASIC WT.	3,955
RADIATOR/METEOROID PROTECTION & INSULATION (NOT SHOWN)	1,531
TOTAL	5,486

72-1671

SORTIE RAM STRUCTURE
Details

The basic structure consists of a 160-inch diameter cylindrical section 120 inches long sandwiched between two 45-deg. conical bulkheads. The forward end has a barrel section 102 inches in diameter and 8 inches long attached to the conical bulkhead to the MDAC docking adapter. The aft end has a spherical closure bolted to the conical bulkhead.

The docking adapter carried throughout this study is the design developed by MDAC for the Modular Space Station. The 102-inch diameter adapter is made from a one-piece roll ring forging of 2219-T852 aluminum alloy as an integrally machined thick wall cylinder with end bolt circle flanges.

The cylindrical section consists of three panels 120 inches long formed to the 160-inch inside diameter. It has two primary end rings 8 inches deep with I cross-sections. Two longitudinal I-beams are welded into the cylindrical section at a location approximately 15-deg. above the horizontal centerline. The beam at the left side looking forward is 12 inches deep; the other beam is 3 inches deep. The three segments of the cylinder span between the two beams and from these beams to the bottom centerline. The cylindrical panels are made with an integrally machined waffle grid stiffener. The type of waffle selected is a 5-inch 90-deg. square grid with the stiffeners on the outside of the module.

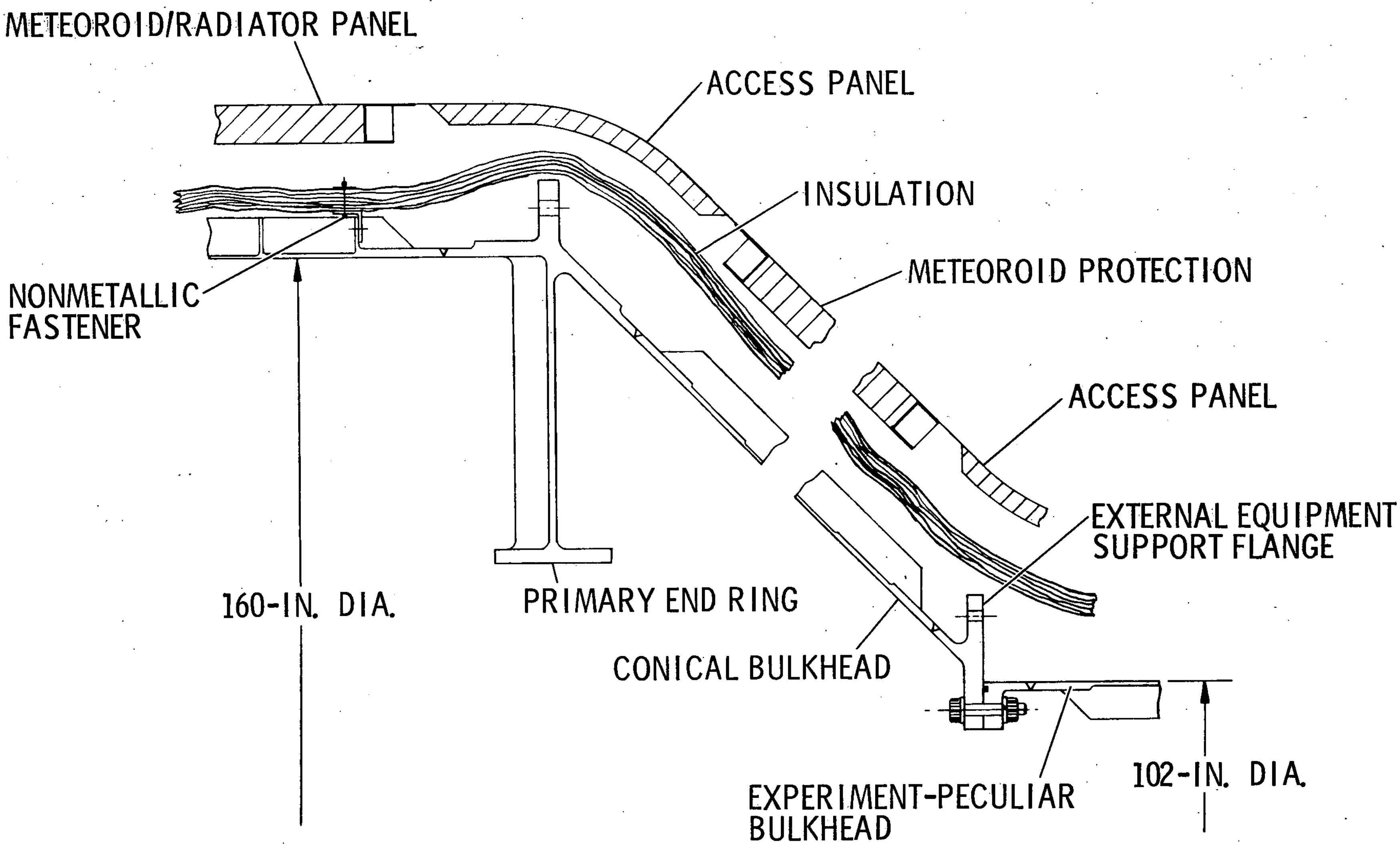
The 45-deg. conical bulkhead makes the transition between the 160-inch diameter cylindrical sidewall and the MDAC docking adapter.

The closure bulkhead forms a simple membrane closure for the aft end of the Sortie RAM. The membrane is a portion of a sphere and is welded to a ring that is bolted to the 102-inch diameter interface.

The radiator/meteoroid bumper is made from a sandwich of 0.016-inch outer and 0.010-inch inner aluminum skins bonded to a high-temperature polyurethane foam core. The radiator/bumper panels cover the cylindrical portion of the module and are split into sets of eight 45-deg. sections.

The RAM/orbiter attachment fitting concept selected for RAMs is a five-point reaction statically determinant system. The five fittings on the orbiter were assumed to be of ball or trunnion mount from located at 93 inches from the YZ centerline and 25 inches above the YY axis. The fittings on the RAM include three tripod types, only one of which reacts the longitudinal load, and two simple A-frames which only react lateral loads.

SORTIE RAM STRUCTURE
Details



72-1760

STRUCTURAL SUBSYSTEM
Sortie RAM

The pressure wall thickness of the cylindrical sidewall was selected on the basis of manufacturing minimums and because it is an optimum design (minimum structure weight) for the waffle structure. At these thicknesses the operating stresses are low, yielding high critical crack lengths.

For commonality all meteoroid bumpers have been standardized; the primary bumper is 0.016 inch and the secondary bumper is 0.010 inch thick. The function of the secondary bumper is to protect the insulation from fragments resulting from meteoroid penetration of the primary bumper. The insulation selected is Superflox, which is kept in place by means of nonmetallic fasteners, such as Teflon or nylon, to minimize heat shorts. There were determined by the penetration probability requirements, the surface area of the largest pressurized module, and by the longest RAM mission.

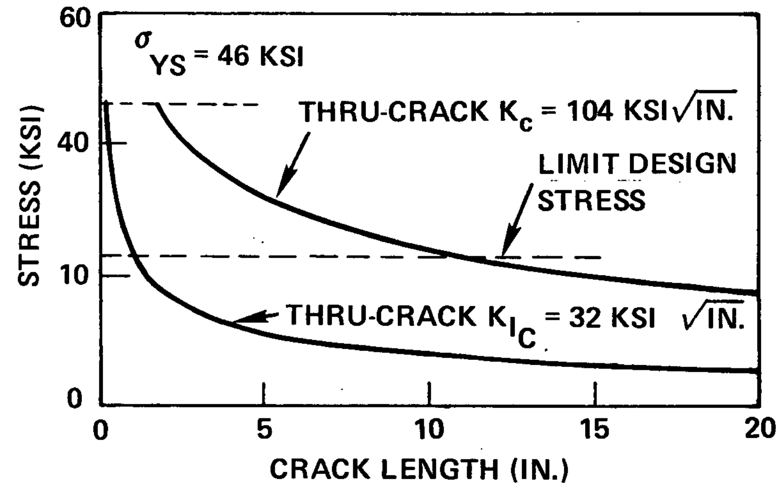
The five-point RAM/orbiter attachment fitting concept was derived from the requirement of static determinacy. One implication of this requirement is that the longitudinal loads are reacted at one location; this load results in a large couple or moment induced into the module sidewall. An internal beam structure was selcted for this task as it yields the lowest weight system, is the best from manufacturing considerations, and – most important – cuts neither through the radiator system nor induces thermal shorts into the basic module structure.

Data developed in this study shows that 2219-T851 aluminum alloy is the best material for components of the pressurized RAM module. It was selected on the basis of its excellent corrosion resistance, fracture toughness, weldability, and machinability.

STRUCTURAL SUBSYSTEM
Sortie RAM

BASIC SUBSYSTEM PARAMETERS

- 0.070-IN. PRESSURE SHELL THICKNESS
- 0.016-IN. METEOROID BUMPER
- 0.010-IN. SECONDARY BUMPER
- FIVE-POINT RAM/ORBITER ATTACHMENT
- INTERNAL BEAMS FOR ORBITER ATTACH FITTINGS
- 2219 ALUMINUM ALLOY



RATIONALE FOR SELECTION

- MANUFACTURING MINIMUMS
- P_0 = 0.995 FOR 1.0 YEAR
- PROTECTION OF INSULATION
- BY STATIC DETERMINACY
- TO REDUCE HEAT SHORTS & NOT REDUCE RADIATOR AREA
- WELDABILITY, FRACTURE TOUGHNESS & CORROSION RESISTANCE

IMPORTANT TRADE STUDY RESULTS

- SIDEWALL STIFFENING REQUIREMENTS MINIMAL WITH 0.070-IN. SKIN THICKNESS
- WAFFLE GRID SIDEWALL - LIGHTEST
- LONG LIFE CONSIDERATIONS - NOT CRITICAL
- SMALL WEIGHT PENALTIES IMPOSED IF MODULES DESIGNED TO MAXIMUM LOADS FOR ALL MODULES

72-1796

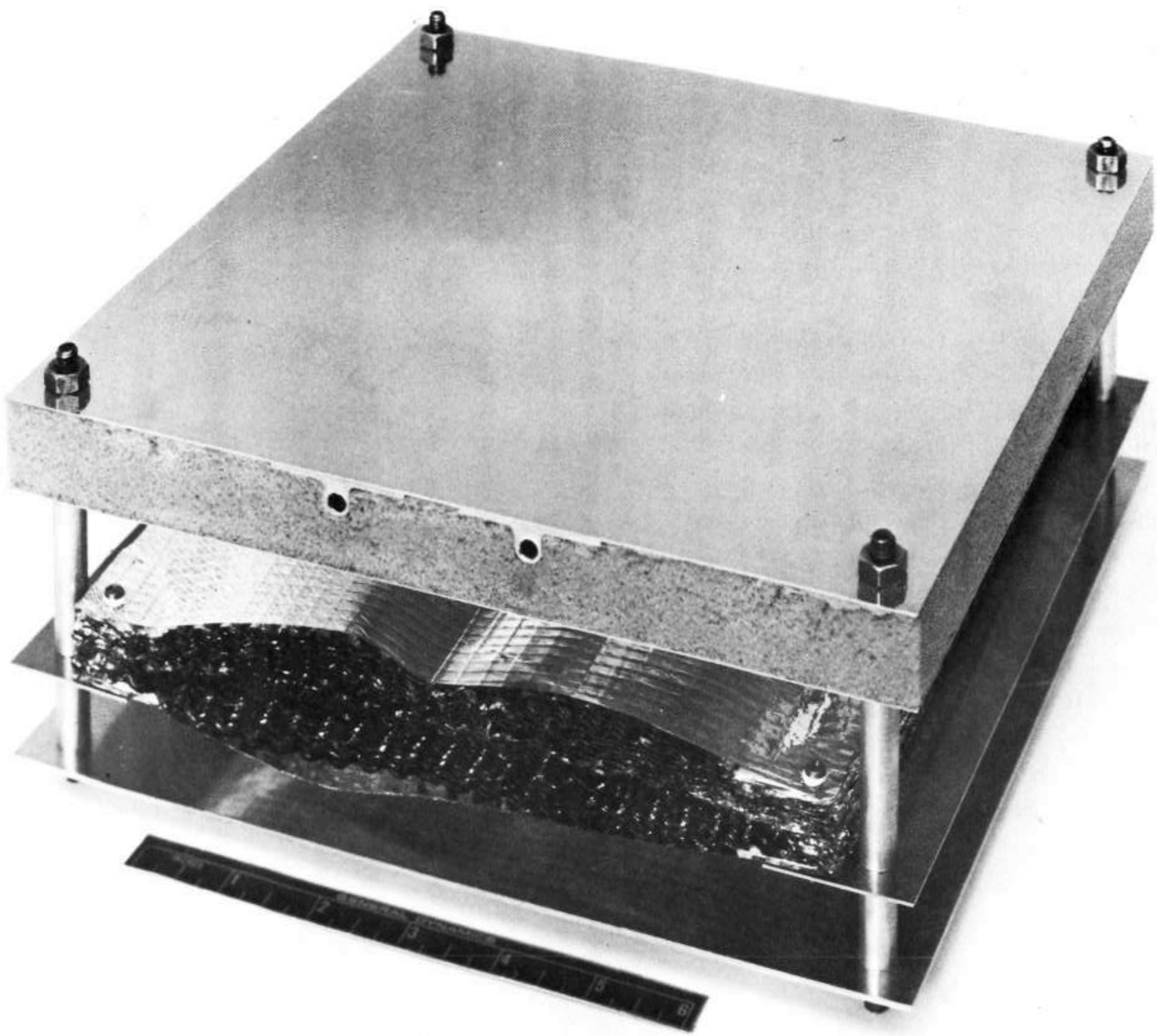
TEST PANELS

The approach to the RAM structural design is to separate the functions of the pressure shell and the environmental protection systems. The waffle grid stiffened shell structure will carry all pressure, bending, and axial loads. The environmental protection system consisting of the meteoroid bumpers and radiators will carry only structural loads imposed by its own inertia and by acoustic and vibratory conditions. Thermostructural loads from the radiator must not be applied to the pressure shell so that stresses are minimized. The function of the radiator and the meteoroid bumper have been integrated within the environmental system. A secondary meteoroid bumper system has been adopted because of the probability of a large number of penetrations of a single bumper and the subsequent damage to the high-performance insulation.

The design of the environmental protection system for the RAM modules is a combined radiator and meteoroid bumper that is made in 45-deg. cylindrical segments; each segment is approximately 66 inches wide and either 8 or 10 feet long dependent on the module sidewall length. The radiator is made into cylindrical barrels 14 feet in diameter. The radiator is made as a sandwich structure with an outer 0.016-inch thick meteoroid bumper acting as the radiator fin. The inner bumper is 0.010-inch thick and separated 1.0 inch from the outer bumper by I-shaped stiffeners that also house fluid passages; other D-shaped fluid passages are attached to the outer bumper skin only. Polyurethane foam is bonded between these stiffeners and to the inner and outer bumpers.

The adoption of this design for the RAM is based on current knowledge and preliminary analysis. Test panels similar to those shown opposite will be used to find the ballistic limit of the 0.016-inch outer and the 0.010-inch inner bumper, and the 1.0-inch polyurethane foam. They also will be used to determine the effectiveness of the polyurethane for protecting the insulation.

Other test panels will be used to determine the need for sandwich construction for acoustic fatigue, to find acoustic transmission losses, and to define the acoustic environment inside the module.



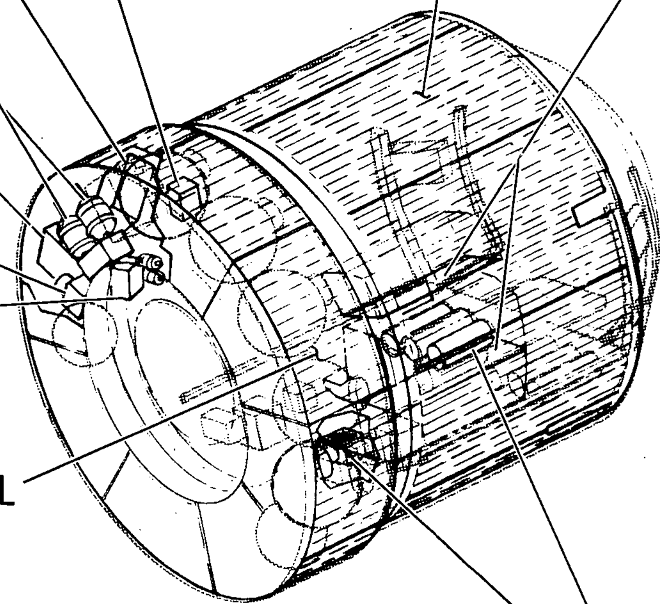
THERMAL CONTROL SUBSYSTEM
Sortie RAM

The thermal control subsystem uses a dual-fluid concept. Water is used in the habitable areas to avoid toxicity and flammability hazards. Freon 21 is used in the radiator circuit since the radiator temperature can be well below the freezing point for water in some cases.

A bypass valve around the radiator regulates the Freon temperature to 35F and provides control for variations in internal and external loads. There are two completely independent systems in the radiator field over the main hull, with each system capable of carrying the entire cooling load, thereby providing redundancy in event of component failure. The radiator field over the external equipment bay does not contain the redundant cooling loop.

For closed shuttle door operation and transient peak heating periods a water sublimator and thermal storage element (TSE) are provided. An interface heat exchanger (GSE Hx) receiving coolant from ground support equipment is used during prelaunch and postlanding. The TCS interfaces with EC/LS at air to liquid heat exchangers where cabin sensible and latent loads are absorbed by the TCS. In addition, the Freon loop is used to warm the cabin oxygen supply.

THERMAL CONTROL SUBSYSTEM
Sortie RAM



ITEM	WEIGHT (LB.)
PUMPS & ACCUMULATORS	61
HEAT EXCHANGERS	209
WATER SUBLIMATOR	136
HEAT STORAGE ELEMENTS	300
PLUMBING VALVES & MISC.	192
RADIATORS	(1,531)*
TOTAL (DRY)	898
FLUIDS	513
TOTAL	1,411

* RADIATOR (INDUCED ENVIRONMENTAL PROTECTION) WEIGHT ASSIGNED AS PART OF STRUCTURAL WEIGHT

72-1672

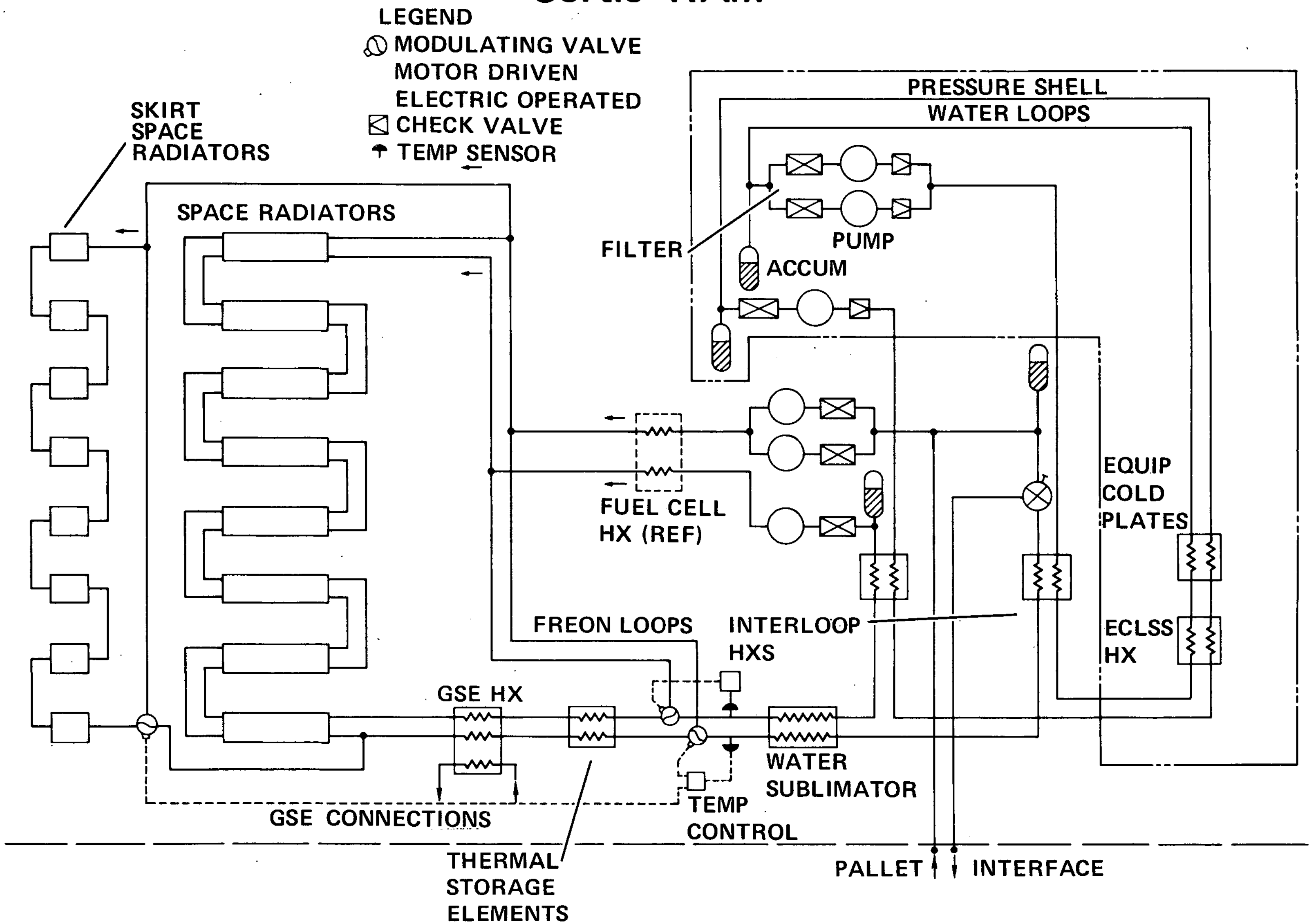
THERMAL CONTROL SUBSYSTEM SCHEMATIC
Sortie RAM

The sortie RAM thermal control subsystem is comprised of two fluid systems. Water is used in the habitable compartment because of safety and excellent heat transfer capability. The water transfers heat from all interior heat sources to an external Freon 21 system across an interloop heat exchanger. This heat, and heat rejected by the fuel cell, is transferred to the radiator panels and rejected to space. The Freon supply temperature to the intercooler is maintained at a nominal value of 35F by a radiator bypass control. Thermal damping during periods of rapid transients or peaking loads is provided by the thermal storage element, which is sized for the re-entry condition when neither the radiators nor the sublimator can be used. The sublimator is used for on-orbit cooling during periods when the cargo bay doors are closed. Redundancy is provided in both loops, except for the skirt radiators, by using two independent circuits for each loop.

The subsystem interfaces with a ground coolant supply through the GSE heat exchanger. This supplies cooling during prelaunch and postlanding operational phases.

The subsystem also interfaces with the environmental control life support subsystem (EC/LS) through the EC/LS heat exchanger. Because this heat exchanger is a condensing heat exchanger to provide humidity control, this demand fixes the minimum fluid temperature requirement resulting in the Freon design control point of 35F.

THERMAL CONTROL SUBSYSTEM
Sortie RAM



72-1763

THERMAL CONTROL SUBSYSTEM
Sortie RAM

The basic subsystem parameters shown were based on plus-three-sigma heating for the space radiators and shuttle equipment performance for the sublimator. The thermal storage element was sized for 1.5 hours of operation which includes a 30-minute postlanding period before ground support equipment (GSE) hookup. A phase change material with heat of fusion of about 90 Btu/lb. was assumed. Comparable thermal storage materials with similar thermal capacity are currently in use. However, the melting point characteristics are not compatible with RAM requirements. The radiator area is that available using the sidewall area plus a three-foot skirt extension.

The methods of heat rejection and thermal control were compared and selection was made based on weight, cost, and system complexity. Radiators were selected because of the weight of sublimed expandables for the loads anticipated over a seven-day mission would be prohibitive. The sublimator was selected for use on-orbit whenthe cargo bay doors are closed. Excess water is available from the fuel cell for this unit and the selected component is common with shuttle equipment. The thermal storage element provides passive control when neither the sublimator nor radiators are usable. Since the functioning of the unit is automatic and requires no moving parts, minimum system complexity results.

The radiator coating selection was based primarily on a comparison of Teflon/Ag/Inconel second-surface mirrors with Z-93 white paint. Radiator panel bypass valves would be required using the paint and a more complex temperature control technique would be required. Use of the second-surface mirror eliminates the panel valving requirement.

A comparison of the effect of using plus-three-sigma heating and nominal space heating values for radiator performance was made. As shown, approximately 20% more heat rejection capability is obtained at a given cabin temperature using the nominal case. It is also shown that selection of cabin air temperatures and/or radiator orientation significantly affects heat rejection capability.

THERMAL CONTROL SUBSYSTEM
Sortie RAM

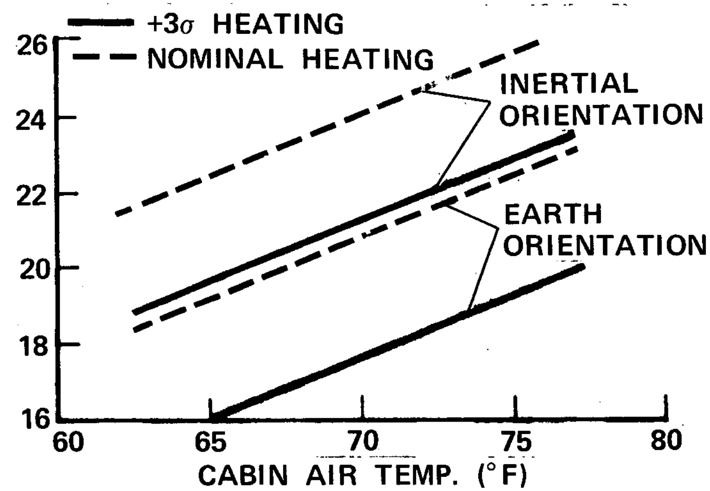
BASIC SUBSYSTEM PARAMETERS

RADIATOR HEAT REJECTION (BTU/HR. -MAX.)

- INERTIAL ORIENTATION: 19,600
- RAM TOWARD EARTH: 16,150
- RAM AWAY FROM EARTH: 20,700

- SUBLIMATOR HEAT REJECTION: 74,000 BTU/HR.
- THERMAL STORAGE: 13,900 BTU
- FREON TEMPERATURE CONTROLLED TO 35°F
- RADIATOR AREA: 531 $FT.^2$

SORTIE RAM RADIATOR PERFORMANCE



SELECTION RATIONALE

- RADIATORS - LOWEST ON-ORBIT WEIGHT
- SUBLIMATOR - FUEL CELL WATER AVAILABLE
- THERMAL STORAGE - SIMPLICITY
- CONTROL TEMPERATURE - HUMIDITY CONTROL

TRADE STUDY RESULTS

- FREON TEMPERATURE CONTROL BY RADIATOR BYPASS
- SUBLIMATOR FOR ON-ORBIT HEAT REJECTION, DOORS CLOSED
- THERMAL STORAGE FOR IN-ATMOSPHERE TEMPERATURE CONTROL
- SECOND-SURFACE MIRROR FEP TEFLON/Ag/INCONEL FOR RADIATOR COATING ($\alpha = 0.09$, $\epsilon = 0.8$)

72-1762

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM
Sortie RAM

The sortie RAM contains an independent EC/LS configured to meet the requirements pertaining to atmosphere storage, atmosphere revitalization and distribution, water management, cabin pressure control, and special life support. Primary control and display of EC/LS functionability and status are located on the C&D console with second-level control and display located at the secondary control panel.

ATMOSPHERE CONDITIONING – The primary processing components that are necessary to revitalize and maintain the module atmosphere within design limits are located under the floor. A filter and debris trap removes atmosphere particulate matter and is replaced when the pressure drop indicates a loaded filter. Downstream of the filter, two fans in parallel provide the atmosphere circulation. Only one fan operates at a time. Lithium hydroxide is used for CO_2 removal and activated charcoal for odor and trace gas removal. A condensing heat exchanger provides humidity control. The condensate is pumped to storage tanks. Revitalized cabin atmosphere flows through a distributing duct network. Air passing through the condensing heat exchanger is bypass controlled to maintain the cabin temperature between 65 and 85F.

PRESSURE CONTROL – A pressure control assembly maintains cabin pressure at 14.7 psia, supplies GO_2 and GN_2 for repressurization and emergency use, and supplies O_2 gas to the cyclic accumulators and N_2 gas to the water storage tanks.

The cabin pressure is maintained at 14.7 psia by controlling the O_2 partial pressure between 3.0 and 3.4 psia and supplying N_2 gas to make up the balance.

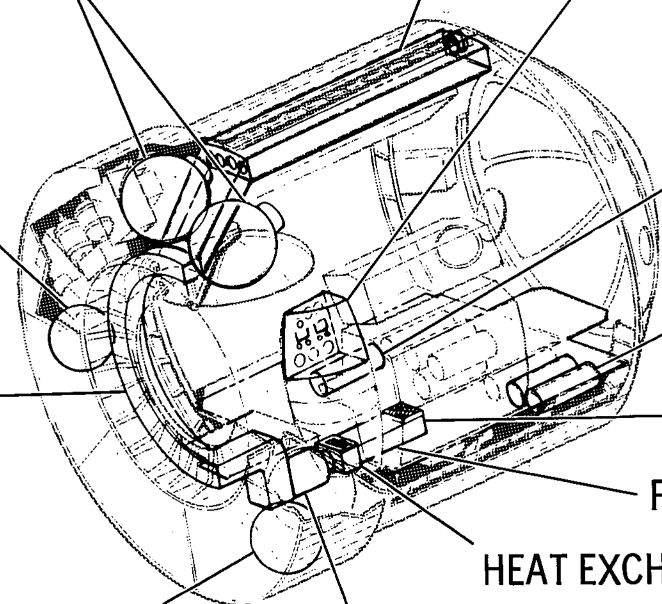
WATER MANAGEMENT – A water management assembly provides for RAM water needs, prevents bacteria buildup, provides storage of fuel cell generated water and condensate from humidity removal unit(s) and supplies water for the sublimator in the TCS. Fuel cell water flows through a H_2 separator and a silver ion resin bed for sterilization.

SPECIAL LIFE SUPPORT – Two subassemblies provide emergency functions of fire detection and IVA support. Fire detection is accomplished by a condensate nuclei counter located in the heat exchanger duct system. Connections for two IVA umbilicals are provided.

GASEOUS STORAGE – Oxygen storage is integrated with the EPS reactant storage. Nitrogen is stored at 3,100 psia in two titanium tanks located in the forward external equipment bay.

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM

Sortie RAM



ITEM	WEIGHT (LB.)
ENVIRONMENTAL CONTROL	562
LIFE SUPPORT	166
TOTAL (DRY)	728
EXPENDABLES (MAX.)	397
TOTAL	1,125

72-1673

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM SCHEMATIC
Sortie RAM

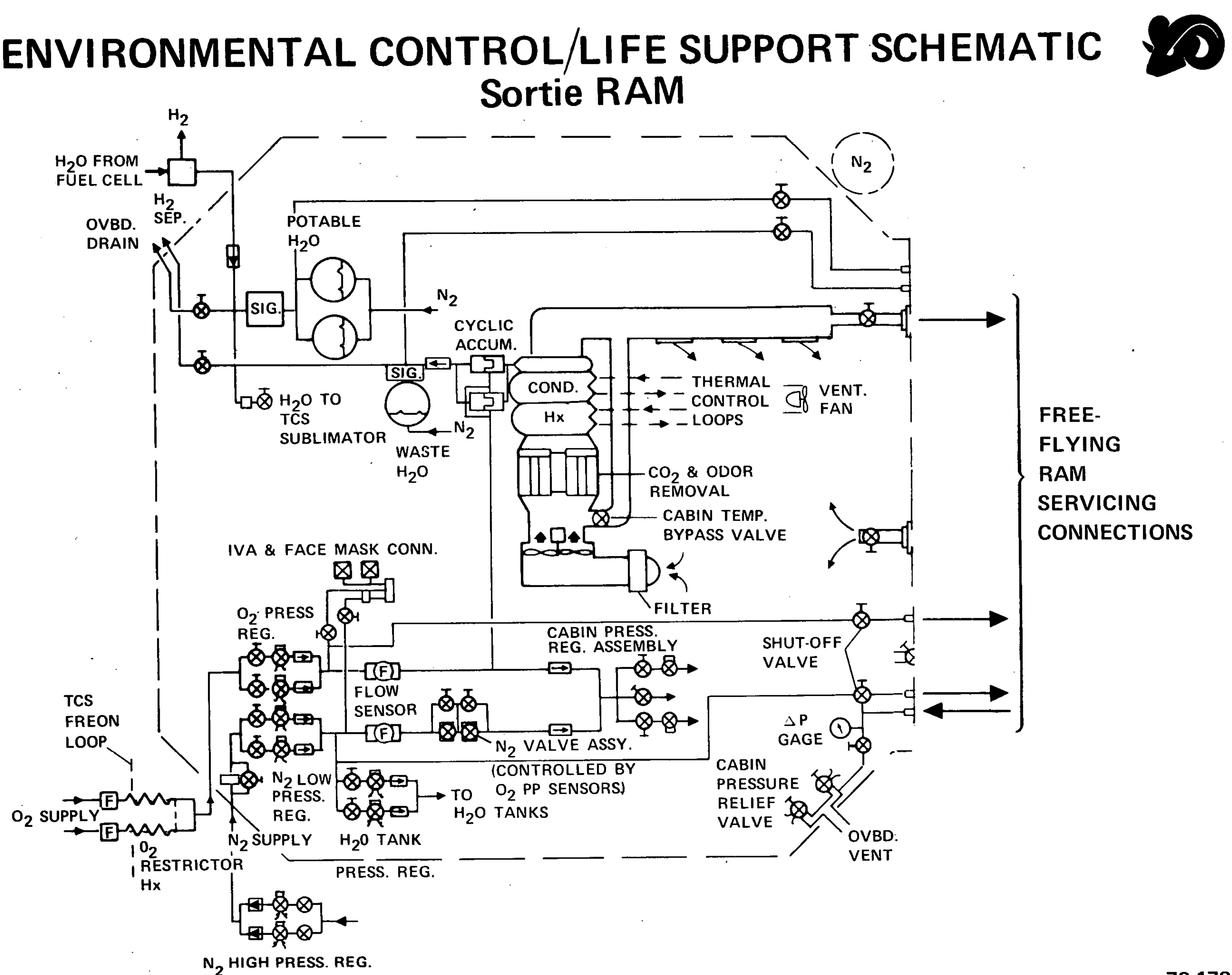
The sortie RAM environmental control and life support subsystem provides for two payload specialists. The system is completely independent from the shuttle except that lithium hydroxide (LiOH) canisters for CO_2 control are stored in the shuttle. The subsystem provides cabin pressure control and maintains oxygen partial pressure. Condensing heat exchangers absorb heat picked up by the cabin air and control the humidity level in the compartment. CO_2 and odors are removed by LiOH and activated charcoal canisters.

All fuel cell water and humidity condensate water collected during the mission is stored in onboard tankage. Water generated by the fuel cell flows through a hydrogen gas separator, which is located externally to the pressurized volume. Before entering the tanks, the condensate passes through a silver ion generator (SIG) to kill micro-organisms that may have entered the water system. In the water line to the sublimator, a filter removes any particles that may be in the water.

Facilities for contingency repressurization and IVA and facemask support are provided. Connections for two IVA umbilicals exist in the sortie RAM. Support is limited to purge flow of oxygen to the IVA suits in the event of contingency depressurized or contaminated cabin operations. The oxygen flood flow rate must be maintained at a minimum of about eight pounds per hour to prevent buildup of heat and the possible collapse of the man from heat prostration.

During free-flyer servicing, atmospheric recirculation between the free-flying RAM and the sortie RAM is accomplished by the sortie RAM. Provisions for pressurizing and depressurizing the free-flying RAM are also included.

ENVIRONMENTAL CONTROL/LIFE SUPPORT SCHEMATIC
Sortie RAM



72-1781

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM
Sortie RAM

The sortie RAM environmental control and life support subsystem (EC/LS) provides for atmospheric storage, water management, atmospheric revitalization, pressure control, fire detection, and IVA and facemask support. The system is completely independent of the shuttle vehicle, except that lithium hydroxide/charcoal canisters for CO_2 and odor control are contained in the shuttle stores.

A two-gas pressure system controls nitrogen flow to maintain a compartment pressure of 14.7 psia while maintaining an oxygen partial pressure at a nominal value of 3.1 psi. A condensing heat exchanger is used to extract heat and moisture in the air to maintain a temperature of 65 to 85F, as selected and to control the relative humidity. The humidity condensate is collected from the heat exchanger and periodically transferred to a waste water storage system sized to store all water collected during the mission. In addition to waste water storage, all fuel cell water generated during the mission is stored in sterile condition in a seperate water storage system. This water is available as required by the sublimator in the thermal control subsystem. All tanks are pressurized to 20 psia with nitrogen which permits transfer of the fuel cell water to the sublimator.

High-pressure nitrogen gas storage is used. Storage capacity is adequate to provide make-up for leakage and to repressurize the vehicle to 11.6 psi partial pressure, should decompression occur. The oxygen is contained in the fuel cell reactant cryo tankage and is sufficient to provide leakage make-up, metabolic needs, vehicle repressurization to 3.1 psi partial pressure once, and IVA support for two men for six hours. Contaminant control is provided by particulate filter, activated charcoal and lithium hydroxide which neutralize or eliminate the major identifiable contaminants. The build-up of metabolically produced carbon monoxide was analyzed and found to not exceed the acceptable physiological limit of 29 milligrams per cubic meter for a seven day mission duration. Assuming no leakage, this limit would not be reached until the 25th day of a missi

The following is a summary of the significant trade studies conducted:

NITROGEN STORAGE – High-pressure gas storage was compared with supercritical cryogenic storage. High- pressure storage was lighter and cost less than cryogenic storage for the gas storage requirements considered.

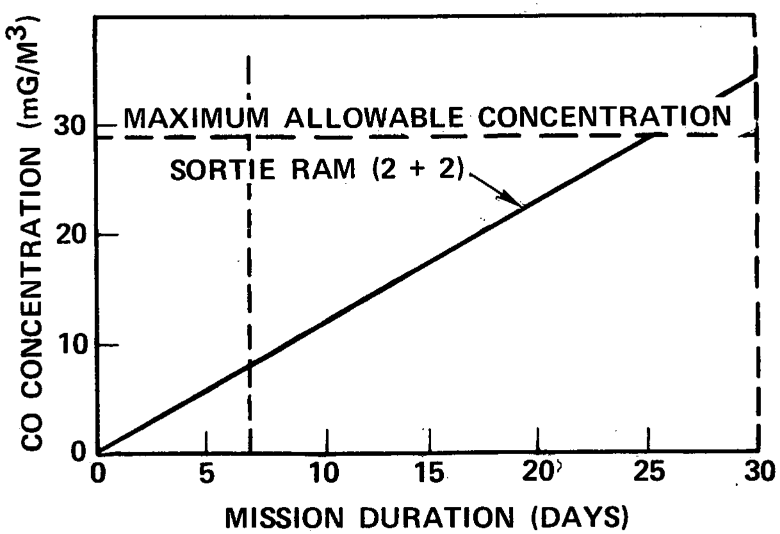
OXYGEN STORAGE – High-pressure gas storage was compared with supercritical cryogenic storage. Since the fuel cell reactants were already stored supercritically, it was advantageous to include the EC/LS oxygen with the fuel cell oxygen.

FREE-FLYING RAM REPRESSURIZATION – A pumping system was compared with a gas store and dump method. The pumping system was rejected because of high power requirements and long pump-down time.

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM
Sortie RAM

BASIC SUBSYSTEM PARAMETERS

•PRESSURE CONTROL (NOM.)	14.7 PSIA
•OXYGEN PARTIAL PRESS.	3.1 PSI
•CO_2 PARTIAL PRESS. (NOM.)	3.0 MM Hg
•H_2O PARTIAL PRESS.	6-13 MM Hg
•AIR TEMP. (SELECTABLE)	65-85 F
•BULK AIR VENTILATION VEL.	20-50 FPM
•TWO-MAN IVA CAPABILITY	



SELECTION RATIONALE

- •TWO-GAS PRESS. CONTROL – SHUTTLE COMMONALITY
- •LiOH/CHARCOAL, CO_2 & ODOR CONTROL – ECONOMICAL, SIMPLE, DEVELOPED
- •CONDENSING HEAT EXCHANGER – HUMIDITY CONTROL
- •SHARE CRYO O_2 WITH EPS – MIN. COST & WEIGHT
- •WATER STORAGE FOR NO EXP. CONTAMINATION
- •IVA CAPABILITY FOR EMERGENCY

TRADE STUDY RESULTS

- •HIGH-PRESSURE N_2 STORAGE
- •SHARE O_2 WITH EPS CRYO O_2
- •HIGH-PRESSURE GAS STORAGE FOR FF RAM PRESSURIZATION

72-1809

CREW HABITABILITY
Sortie RAM

The Sortie RAM is used for missions requiring two payload specialists. Since the orbiter provides all living provisions for two payload specialists, full use is made of the orbiter facilities. For this reason, only those habitability provisions necessary for performing experiment operations are located in the Sortie RAM. These include mobility and restraint devices; miscellaneous items such as cleaning equipment, data, and tools; and emergency equipment such as oxygen masks and IVA suits. Trade studies resulted in the selection of longitudinal floors and a centralized, multipurpose control and display console.

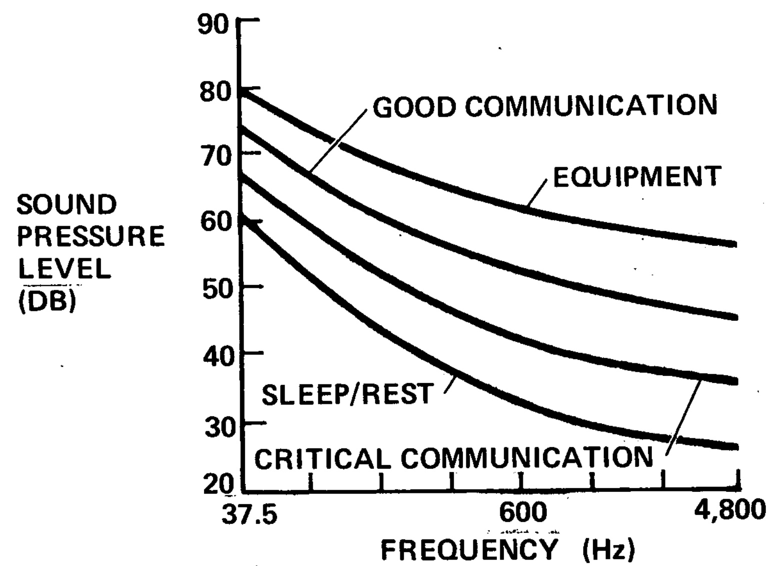
Selected subsystem parameters upon which the RAM element designs are based are shown. These are intended to provide a pleasant and effective working environment for the RAM crew. The set of noise criteria curves shown is typical of the criteria that must be satisfied in the various types of habitable areas.

CREW HABITABILITY
Sortie RAM

BASIC SUBSYSTEM PARAMETERS

- RAM CREW SIZE: 2
- FREE VOLUME: 750 FT^3/MAN
- WORK STATION LIGHT: 30-50 F. C.
- ACOUSTIC NOISE: 50 db 600-4,800 Hz
  70db <600 Hz
- SURFACES TEMP: 105°F MAX.

NOISE CRITERIA CURVES



SELECTION RATIONALE

- MINIMUM FOR PAYLOAD OPERATIONS
- LIVING SPACE & WORK STATIONS
- EFFICIENT FUNCTIONING
- COMMUNICATIONS
- HUMAN TOLERANCE

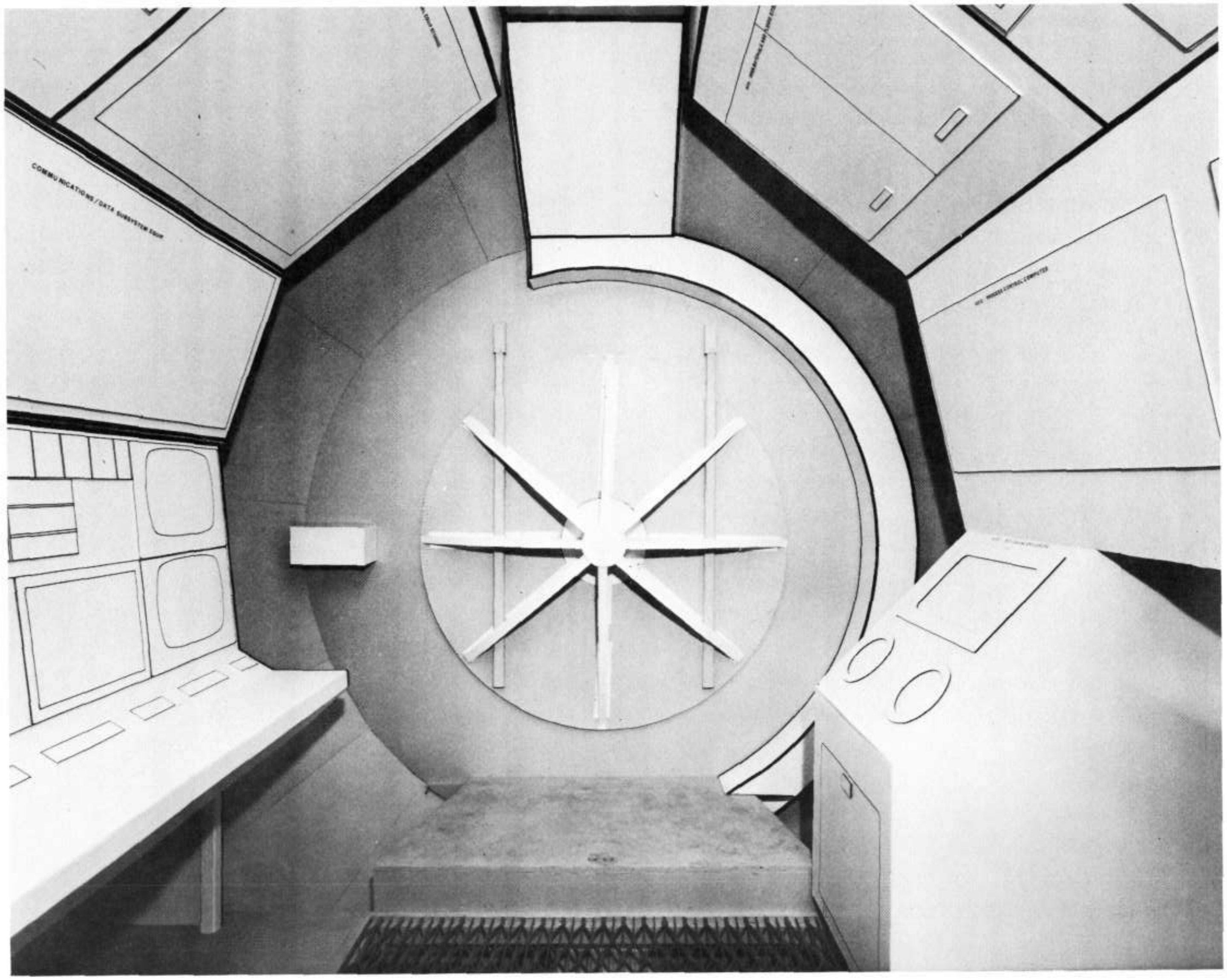
TRADE STUDY RESULTS

- LONGITUDINAL FLOORS
- CENTRALIZED C&D CONSOLE
- O_2 MASKS & IVA SUITS FOR EMERGENCY

72-1786

SORTIE RAM SOFT MOCKUP

This view looking forward, relative to the orbiter, inside the sortie RAM soft mockup shows the location of the air distribution duct around the 60-inch diameter hatch opening and within the 102-inch attachment structure cyclinder. At the left side is the C&D console; at right, a floor-mounted experiment equipment cabinet is shown. Other experiment rack-mounted equipment and standard storage provisions are shown above the centerline.


COMMUNICATIONS / DATA SUBSYSTEM EQUIP

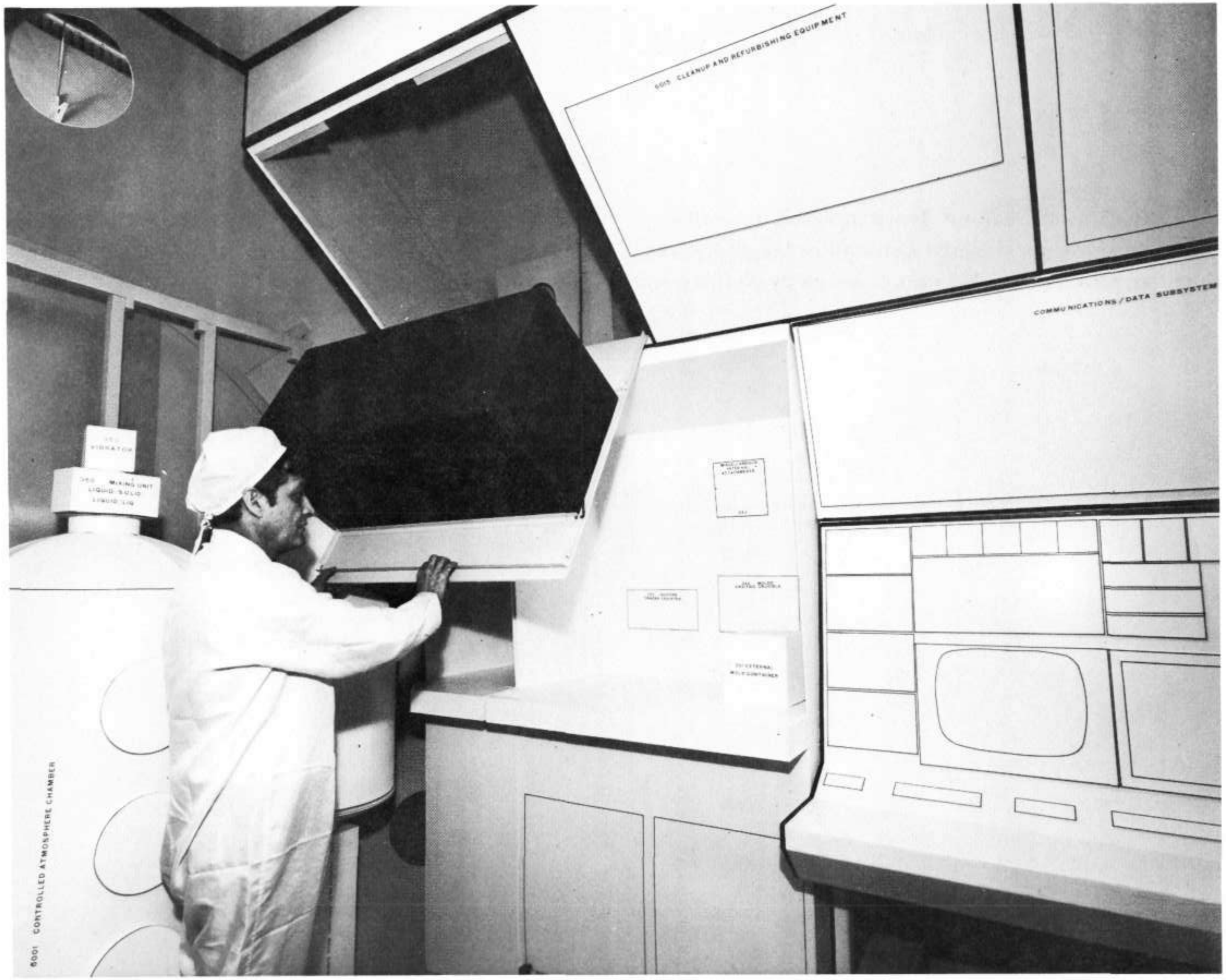
SORTIE RAM SOFT MOCKUP

This view looking aft, relative to the orbiter cargo bay, in the sortie RAM soft mockup shows the relative location of the volume set aside for experiment installation to the permanently installed provisions of C/D console (on the right) and storage/subsystem equipment racks in the rear overhead. A simulation of experiment sample placement into a controlled atmosphere chamber (Materials Science) by a payload specialist is shown.

PROTECTIVE CLOTHING
COMPUTER
COMMUNICATIONS/DATA SUBSYSTEM EQUIP

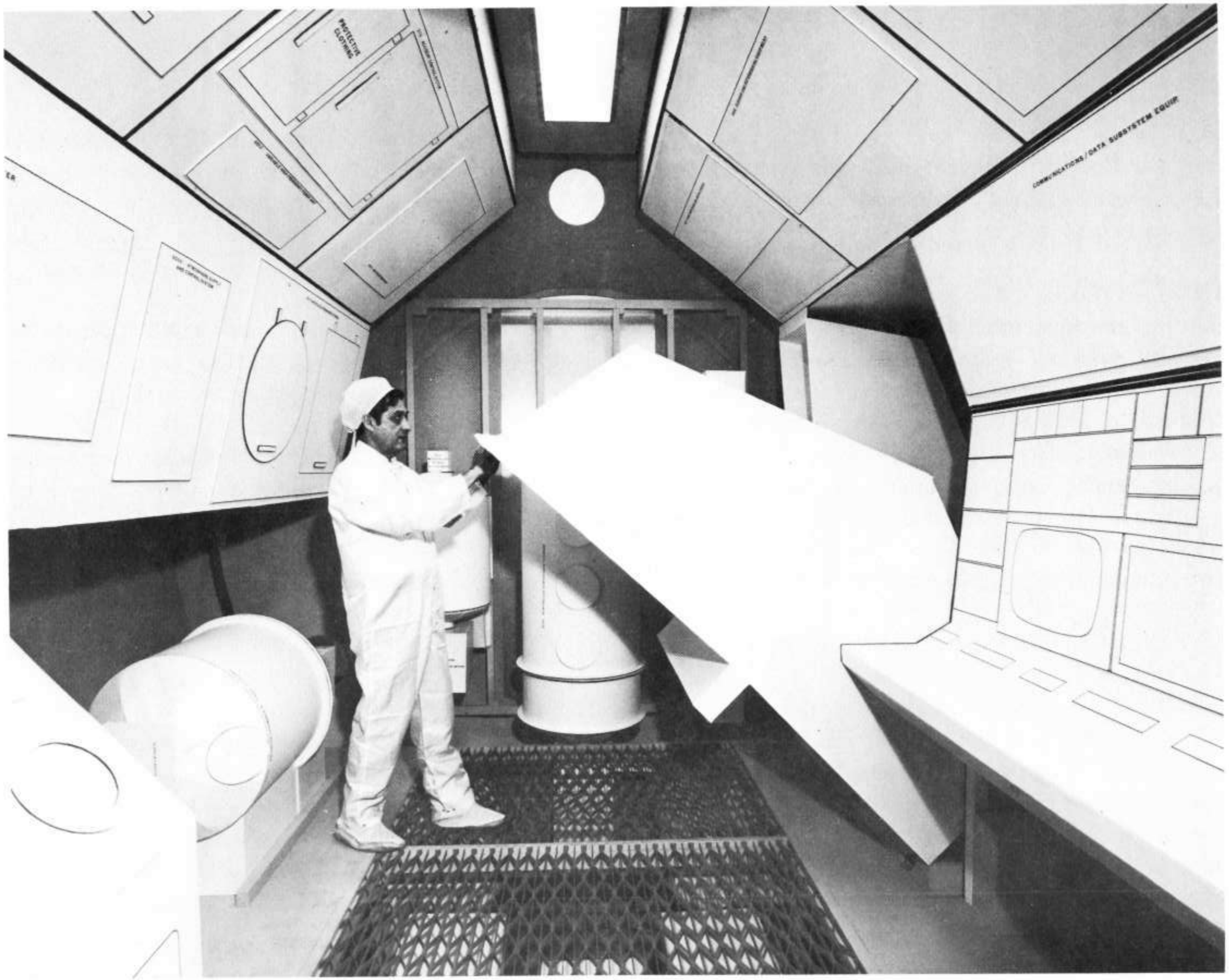
SORTIE RAM SOFT MOCKUP

An accessibility concept suitable for sortie RAM comprises the hinged equipment panel shown. Access is gained both to the equipment itself and to the structural wall and service lines routed in the area. This is applicable both to ground assembly and servicing, and to potential on-orbit troubleshooting of a minor nature, if found necessary.


6015 CLEANUP AND REFURBISHING EQUIPMENT
COMMUNICATIONS/DATA SUBSYSTEM
6001 CONTROLLED ATMOSPHERE CHAMBER

SORTIE RAM SOFT MOCKUP

Accessibility to the area behind large installed assemblies, such as the rack shown, is gained by a floor-located pivot arrangement that locks to the upper secondary structure frame. The C&D console is also arranged in this way. Installation and removal, as well as accessibility, are eased by the approach.


PROTECTIVE CLOTHING
COMMUNICATIONS / DATA SUBSYSTEM EQUIP.

ELECTRICAL POWER SUBSYSTEM
Sortie RAM

The electrical power subsystem provides electrical energy, conditioning, and distribution for module subsystems and the integrated experiment payloads. Two power sources, primary and essential, are provided to meet safety requirements.

POWER GENERATION – The primary power source is a single fuel cell of the type under development for the shuttle program. Present fuel cell design is based on 7-kw average power output with a peaking capability of 10 kw for 0.1 hour. Output voltage is 24 to 32 volts. Operational life design goal is 2,000 hours. The fuel cell, reactant tanks, and supporting equipment are mounted in the external equipment bay. If the primary system fails, the orbiter provides power to operate the essential components of the EC/LS, lights, communication, and status display.

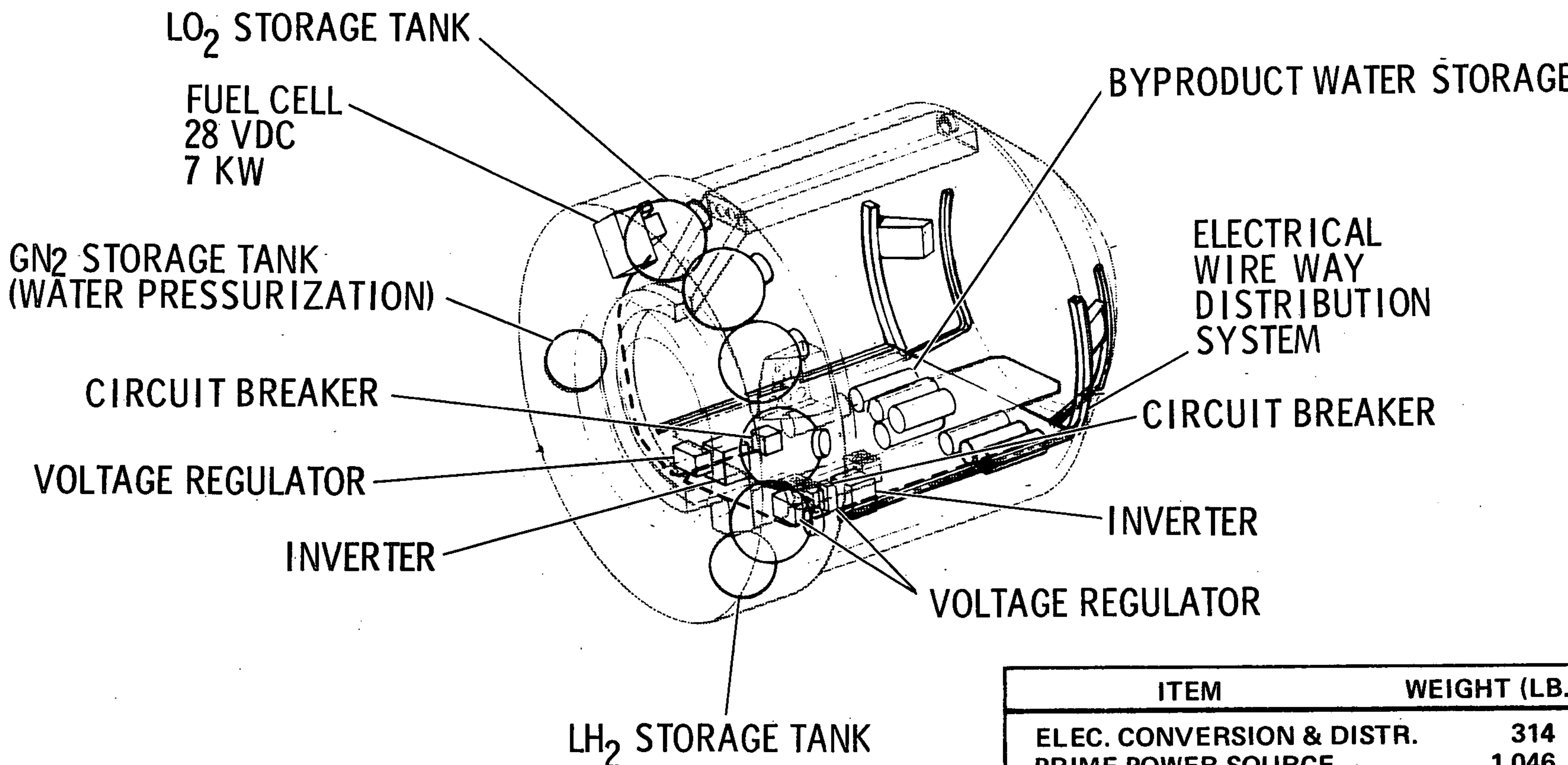
DISTRIBUTION, CONDITIONING AND CONTROL – The EPS provides three independent power channels: a main bus, and two essential (emergency) buses and control. Power from the fuel cell is routed to main bus "A". Power distributed by the main bus "A" supports the ac-dc loads (including essential loads) and the experiment loads. The two essential buses are powered from the orbiter through two separate cables mated at the interface adapter assembly and which connect to wireways leading to essential bus "B" under the floor on the left side and separately, to essential bus "C" under the floor on the right side. The electrical monitoring and control package provides for fault sensing and mode selection by controlling the bus contactors. Provisions are included to interface with either an attached pallet or a free-flyer and maintain the safety requirements for all elements.

Other major components are located under the floor, on and behind the secondary control panel, on the control console and internally throughout the module.

LIGHTING – General area illumination is provided with fluorescent lights. Spot or high intensity lighting is via incandescent lights. Emergency lighting uses independent circuits with independent fixtures. Work area lighting is arranged so that lights may be dimmed to conserve energy.

AUXILIARY POWER GENERATION – For payloads demanding power above the primary generation ability (7,000 watts), auxiliary energy sources are incorporated as experiment integration equipment. Auxiliary kits consisting of 500 amp.-hr. silver-zinc batteries can be provided for peaking purposes to meet experiment package requirements. The batteries are a Skylab CSM design rated at 15 kw-hr. and can be recharged six cycles (50 to 70% DOD). Battery charging is typically required for Materials Science payloads.

ELECTRICAL POWER SUBSYSTEM
Sortie RAM



ITEM	WEIGHT (LB.)
ELEC. CONVERSION & DISTR.	314
PRIME POWER SOURCE	1,046
ELECTRICAL WIRING	423
TOTAL (DRY)	1,783
EXPENDABLES (MAX.)(790 KWH)	800
TOTAL	2,583

72-1674

ELECTRICAL POWER SUBSYSTEM SCHEMATIC
Sortie RAM

The primary power source is a single fuel cell of the type and capacity under development for the shuttle. The fuel cell generates 7 kw of power and cryogenic reactant storage provides a basic energy capacity of 1,034 kwh.

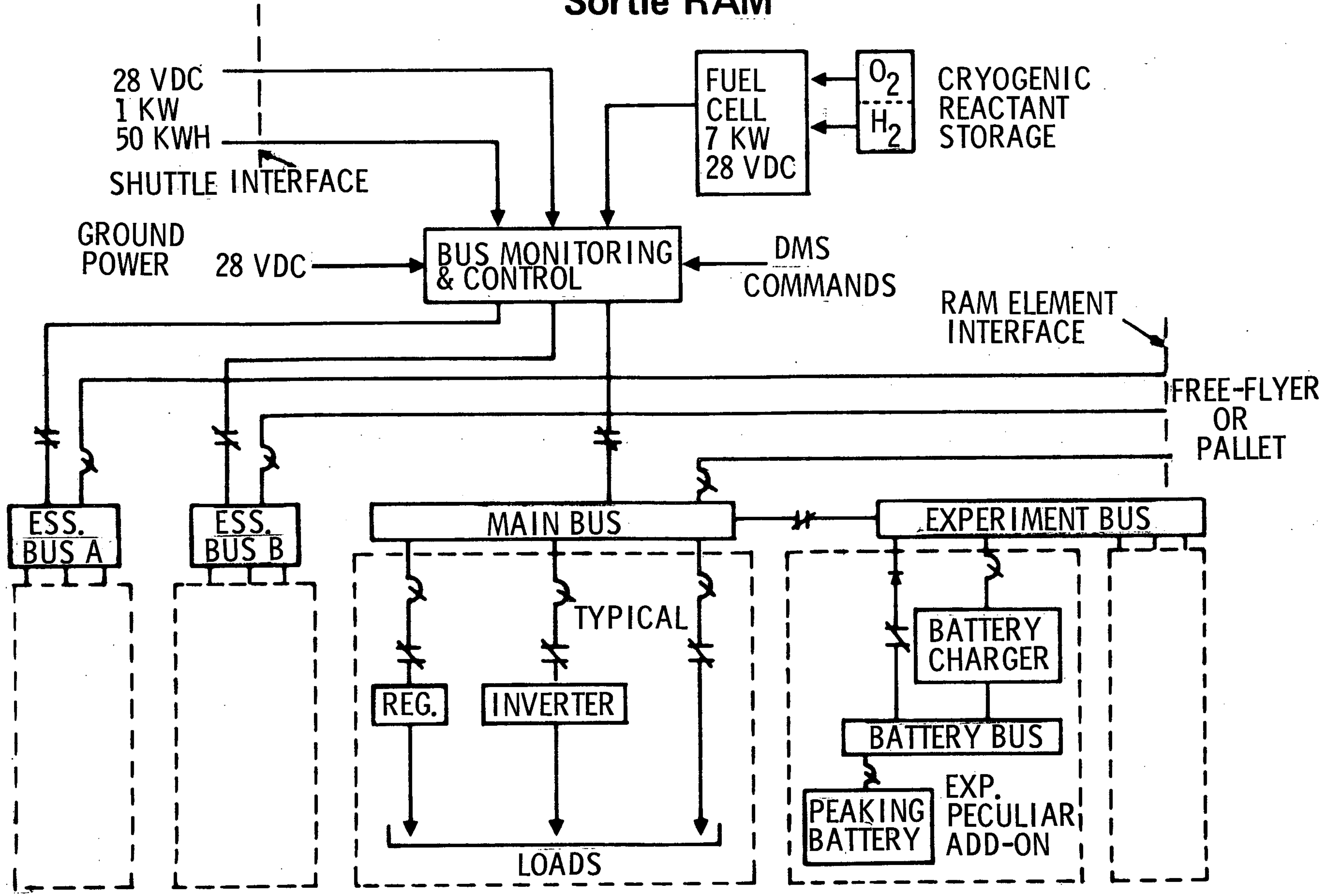
The monitoring and control package is internally redundant and provides for fault sensing and mode selection by controlling the bus contactors. The distribution is at 28 vdc by means of three independent power channels; a main bus and two essential (emergency) buses. The main bus powers all normal operations, including an experiment bus; the essential buses satisfy safety rquirements. The two essential buses are powered from the shuttle. Provisions are included to interface with either an attached pallet or a free-flying RAM and maintain safe backup capability for all elements.

A generally centralized conditioning concept is used. The distribution and conditioning provide unregulated 28 vdc, +5% regulated 28 vdc, and 115/200 vac, 400 Hz, power for subsystems and experiments.

Auxiliary power in the form of Ag-Zn batteries is provided as experiment integration equipment for load peaks which exceed the 7-kw capacity.

ELECTRICAL POWER SUBSYSTEM SCHEMATIC

Sortie RAM



72-1662

ELECTRICAL POWER SUBSYSTEM
Sortie RAM

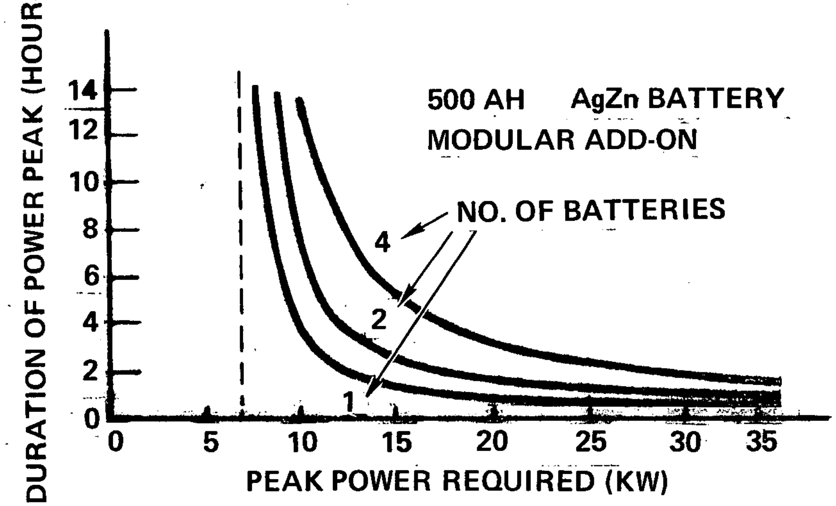
Electrical power levels greater than the capability of the primary power generation capacity (7 kw) are required for certain experiment payloads. For these payloads, auxiliary energy sources are incorporated into the EPS design as modular add-on, experiment integration equipment. The auxiliary power kits consist of a 500-AH Ag-Zn battery and, where advantageous, the associated charger. Each battery can be recharged six cycles (50 to 70% DOD). The area under the curves shows the power-time operating domain for various battery quantities.

Trade studies were performed comparing fuel cells to batteries, cryogenic reactant storage to gaseous storage, distribution at 28 vdc, 115 vdc, and 115 vac, and centralized and decentralized power conditioning. Selection and rationale are as shown – minimum early-year and overall program cost is the prime selection criterion.

ELECTRICAL POWER SUBSYSTEM
Sortie RAM

BASIC SUBSYSTEM PARAMETERS

• POWER	7 KW CONTINUOUS
• ENERGY	1,034 KWH (MAX.)
• DISTR. VOLTAGE	28 VDC
• POWER PEAKING	500 AH MODULAR ADD-ON



PEAKING BATTERY SELECTION

RATIONALE FOR SELECTION

• FUEL CELL & CRYO REACTANT STORAGE	LOWEST WEIGHT & COST COMMONALITY WITH SHUTTLE
• DISTR. VOLTAGE	MINIMUM DEVELOPMENT COMMONALITY WITH SHUTTLE
• AgZn BATTERIES	MINIMUM COST TO SUPPLY POWER PEAKS >7 KW

IMPORTANT TRADE STUDY RESULTS

- FUEL CELL PRIMARY POWER SOURCE
- CRYOGENIC REACTANT STORAGE
- 28-VDC DISTRIBUTION - REDUNDANT BUSES
- CENTRALIZED POWER CONDITIONING

72-1663

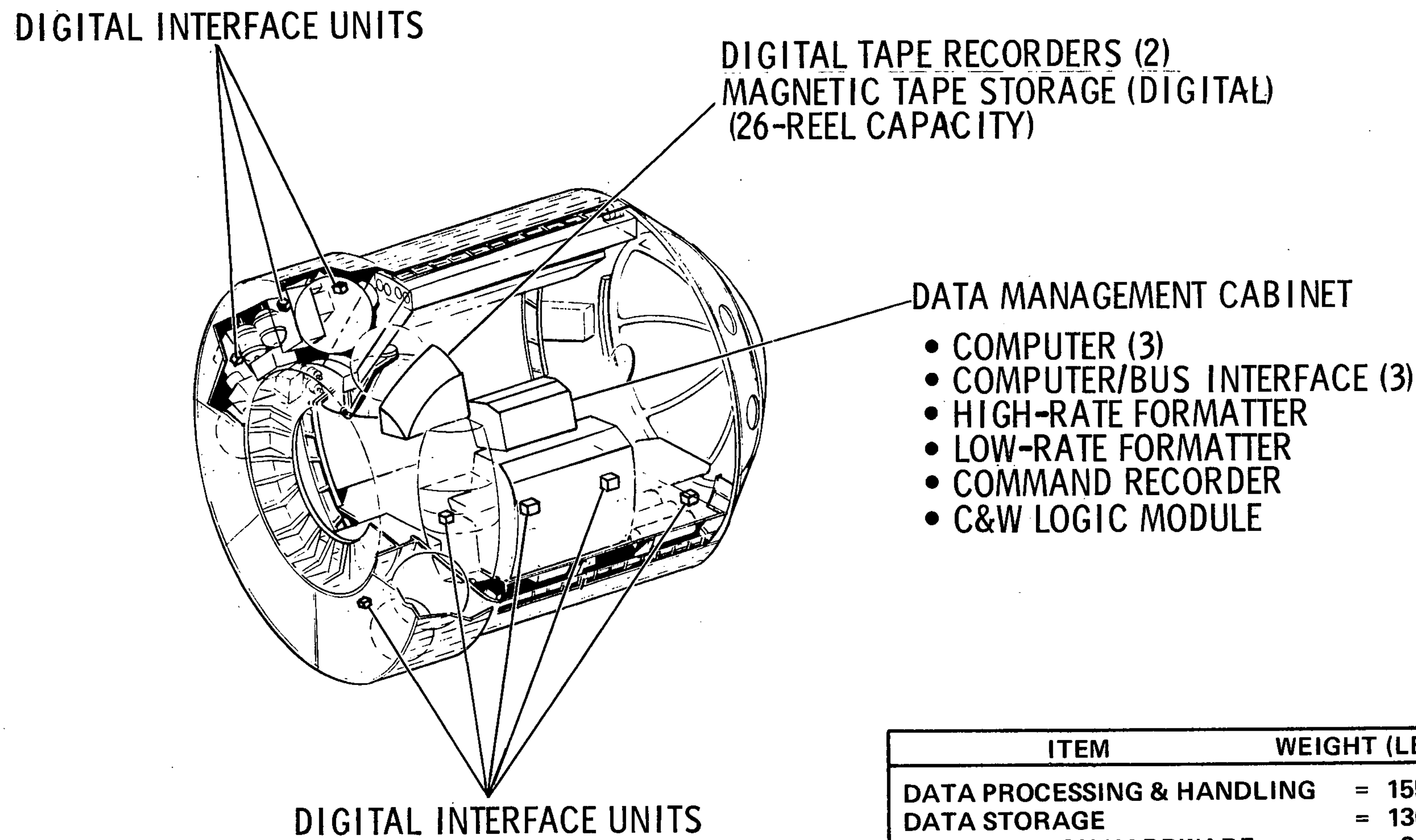
INFORMATION MANAGEMENT SUBSYSTEM
Sortie RAM

The primary components of the communication and data management system are in an enclosure directly above the integrated control and display console. Two digital tape recorders and stowage provisions for up to 26 tapes are located just forward of the main enclosure, in the conical section. Access to the tape recorders is possible without disturbing other crew members at the console.

Digital interface units are located on the interior and exterior of the sortie RAM to relay the pertinent data being monitored.

The prime data handling method is to store data onboard on permanent magnetic tape. Capacity is up to 8×10^9 bits-peak recording rates are up to 220 MBPS. Data processing is via a central computer.

INFORMATION MANAGEMENT SUBSYSTEM
Sortie RAM



ITEM		WEIGHT (LB.)
DATA PROCESSING & HANDLING	=	155
DATA STORAGE	=	136
INSTALLATION HARDWARE	=	29
TOTAL		320

72-1684

COMMUNICATION/DATA MANAGEMENT SUBSYSTEM SCHEMATIC
Sortie RAM

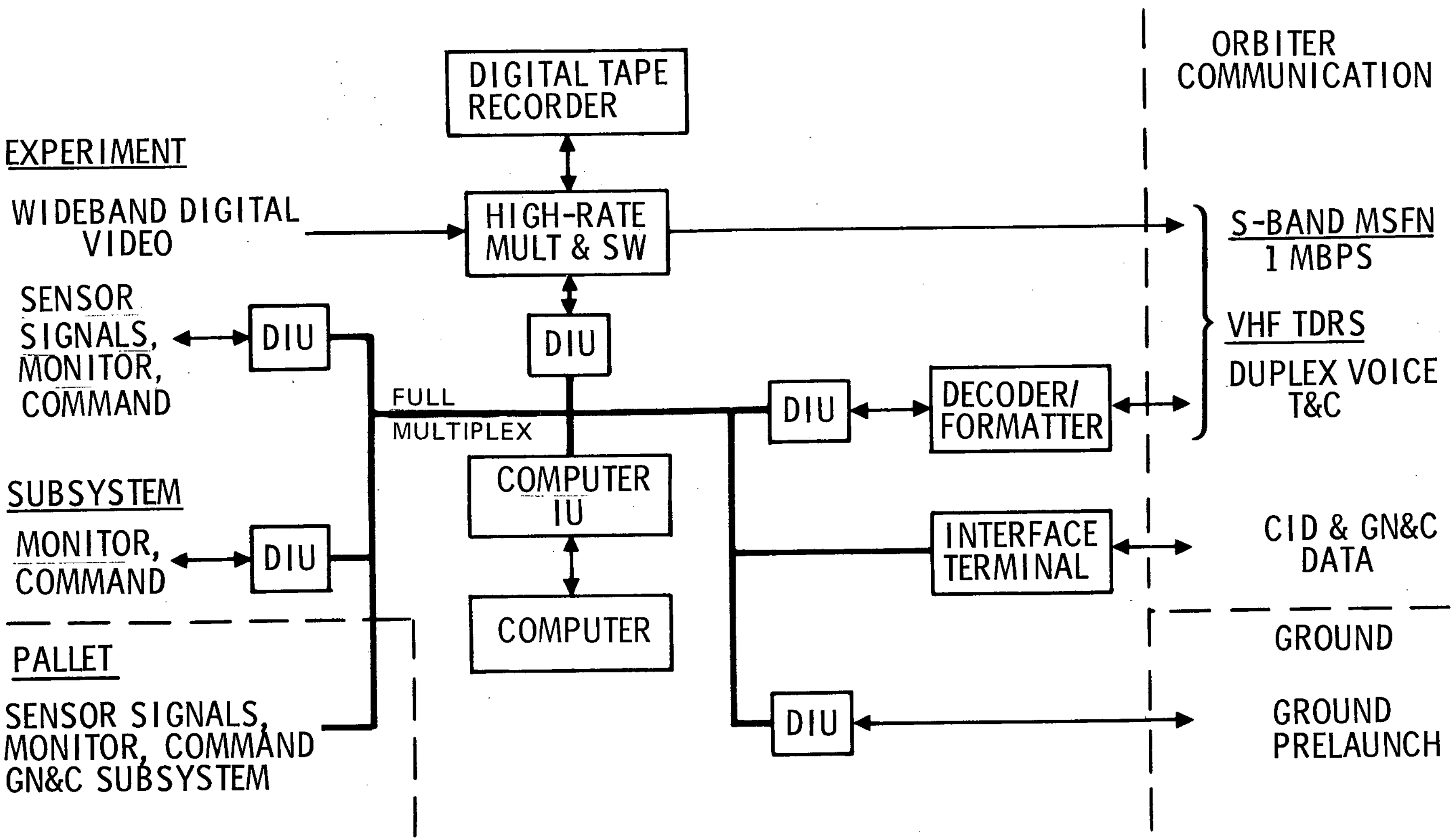
The orbiter provides all communication support for sortie RAM by sharing its VHF/TDRS links (voice, low-rate telemetry, and command) and S-band link to the ground network (1 MBPS digital data transmission).

The basic data handling approach is to store essentially all data onboard on permanent magnetic tape. Data are recorded with volumes up to 1.3×10^{12} bits per mission and at rates as high as 50 MBPS.

A full multiplex (two-way data on a single cable) data acquisition and command distribution system is used to transfer signals between subsystems, experiments, orbiter, and ground prelaunch equipment.

Control, monitor, and automatic checkout of all subsystems and experiments are by a centralized computer configuration. Floating-point hardware is used and three computers provide redundancy to meet safety criteria.

COMMUNICATION/DATA MANAGEMENT SUBSYSTEM SCHEMATIC
Sortie RAM



72-1664

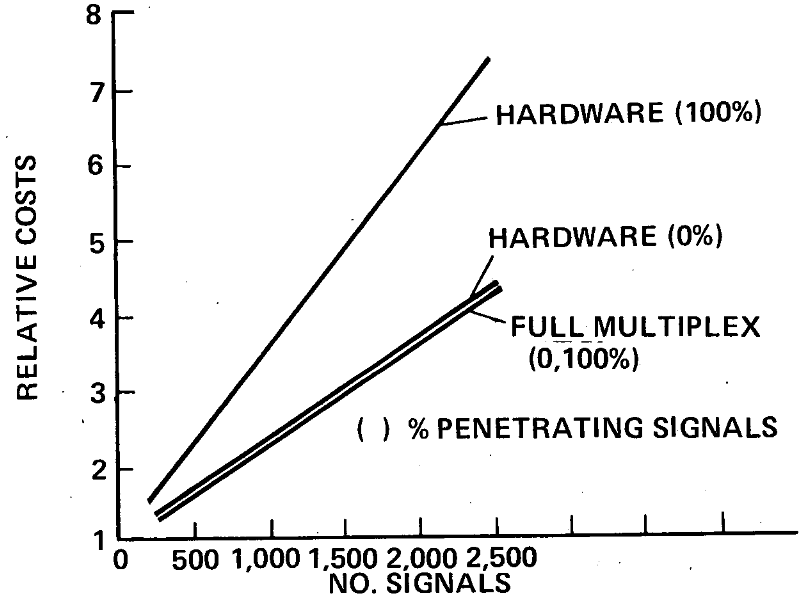
The cost comparison of a full-multiplex data acquisition and command distribution system and a hardwire system is illustrated by the figure. The most significant factor driving costs is the number of penetrating wires (signal sources external to the pressurized area). In the case of the hardwire approach, each penetrating signal requires two wires (one external and one internal) that essentially double test and integration costs relative to nonpenetrating wires. Additionally, the hardwire approach is significantly heavier, more susceptible to EMI, and lacks flexibility relative to the full multiplex system.

Additional trade studies included: centralized versus dedicated computer configurations, digital onboard magnetic tape storage versus RF transmission, and modular versus monolithic software organization. The software trade study selected the modular software structure with modularity to the separable task level because it achieves the lowest total cost for RAM software. Selection and rationale for other trade studies are as shown.

COMMUNICATIONS/DATA MANAGEMENT SUBSYSTEM
Sortie RAM

BASIC SUBSYSTEM PARAMETERS

• SIGNAL INTERFACE CAPACITY	– 1,000
• COMPUTER	– FLOATING POINT HDW.
• PERMANENT TAPE STORAGE	– 1,300 GB/MISSION (MAX.)
• ORBITER TRANSMISSION	– VOICE/DATA



DIGITAL INTERFACE COST COMPARISON

RATIONALE FOR SELECTION

- FULL MULTIPLEX SYSTEM – LOWEST COST, REDUCED EMI, ADAPTABILITY, FLEXIBILITY
- CENTRALIZED COMPUTER – LOWEST PROGRAM COSTS
- DIGITAL MAGNETIC TAPE – LOWEST COST, WEIGHT & POWER
- ORBITER TRANSMISSION – ORBITER AVAILABLE

IMPORTANT TRADE STUDY RESULTS

- FULL MULTIPLEX SYSTEM FOR DATA ACQUISITION & CMD DISTRIBUTION
- CENTRALIZED COMPUTER CONCEPT
- MODULAR SOFTWARE STRUCTURE
- DIGITAL MAGNETIC TAPE STORAGE

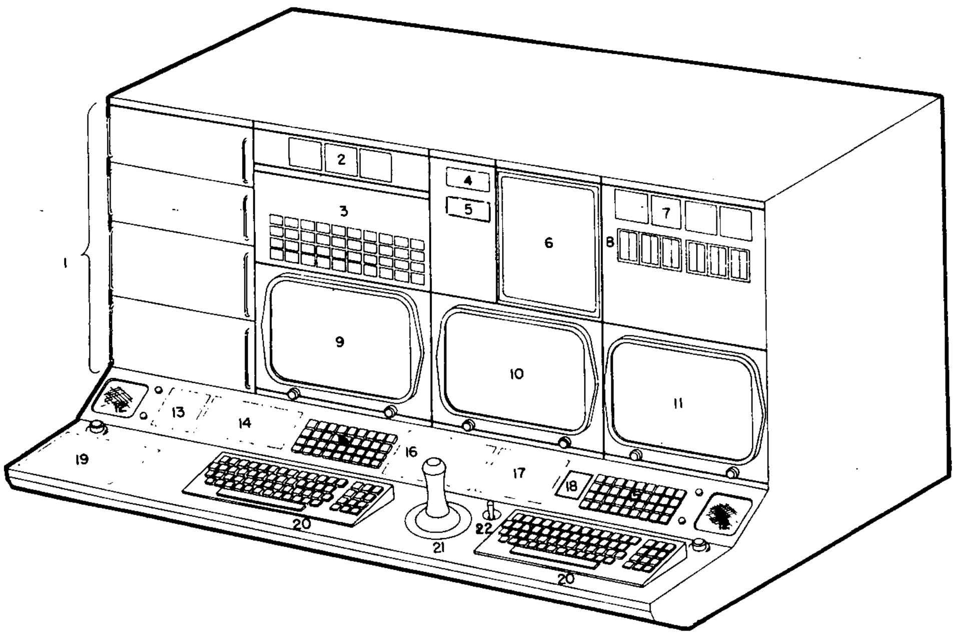
72-1702

7-7

Centralized management of major RAM C&D experiment and subsystem functions is provided by the Data and Subsystem Console. The console provides an optimum mix of conventional, dedicated C&D, and integrated, software-oriented multipurpose C&D. The console is sized for two-man operation. The data management computer provides the console with information through its interface with the subsystems and the experiment payload. Digital interface units provide the interface to the data management computer via the multiplex system, allowing payload and subsystem C&D to be handled by software.

Caution and warning panels located on the Data and Subsystem Console display C&W situation information. The master alarm and C&W indicators are activated when any emergency, caution, or warning situation is detected. Manual intervention is necessary to reset C&W indicators following corrective action.

CONTROLS & DISPLAYS
Sortie RAM



1. DEDICATED EXPERIMENT CHASSIS
2. ADVISORY EXPERIMENT
3. CAUTION & WARNING
4. MISSION TIME
5. EVENT TIME
6. MICROFILM VIEWER
7. ADVISORY SUBSYSTEMS
8. DEDICATED SUBSYSTEMS C&D
9. CRT EXPERIMENT PRIM
10. CRT EXPERIMENT PRIM
11. CRT SUBSYSTEM & CCTV PRIM
12. ICOM SPEAKER
13. ICOM CONTROLS
14. LIGHTING
15. FUNCTION KEYBOARD
16. MONITOR SELECTION CONTROLS
17. CCTV COMMAND CONTROLS
18. CONSOLE EMERGENCY PWR
19. CONSOLE CIRCUIT BREAKERS & PWR DIST.
20. ALPHANUMERIC KEYBOARD
21. 3-AXIS CONTROLLER
22. 2-AXIS CONTROLLER

72-1667

CAUTION & WARNING PROVISIONS
Typical

An analysis was conducted of a representative group of RAM payloads to determine what provisions for caution and warning should be made. The results are summarized on the opposite page.

CAUTION & WARNING PROVISIONS
Typical

EXPERIMENT DISCIPLINE	EMERGENCY	WARNING	CAUTION
ASTRONOMY	NONE	NONE	CRYO COOLING; PRESS. & TEMP.
PHYSICS	TOXIC GAS	DEWAR PRESSURE	PROPELLANT GAS PRESSURE
LIFE SCIENCE	NONE	NONE	SPECIMEN EC/LS STATUS
EARTH SURVEY	NONE	NONE	BOOM & GIMBAL LAUNCH LOCKS
MATERIAL SCIENCE	TOXIC GAS	NONE	NONE
TECHNOLOGY	NONE	LH_2 TANK PRESS.	NONE

EMERGENCY	Evacuate, depressurize, diagnose; safe against loss of life and/or module.
WARNING	Safe against loss of module and/or mission; requires remedial action within 5 minutes to avoid emergency.
CAUTION	Safe against loss of mission and/or equipment, requires remedial action to avoid sustaining the loss.

72-1785

ONBOARD CHECKOUT SUBSYSTEM
Sortie RAM

A number of important trade studies were conducted to establish the most optimum operational configuration and eimplementation on the onboard checkout function. These included: identification of the optimum level of checkout, automatic versus manual operation, centralized versus decentralized checkout, and utility of BITE. Selection and rationale are as shown.

The figure illustrates the results of the level of checkout trade study. The curves shown that system cost penalties incurred without checkout capability are much larger than the cost of including such capability at the subsystem and assembly level, but less than the cost of the checkout capability at the component level. permitting crew participation in those functions performed periodically, or on an on-demand basis, such as

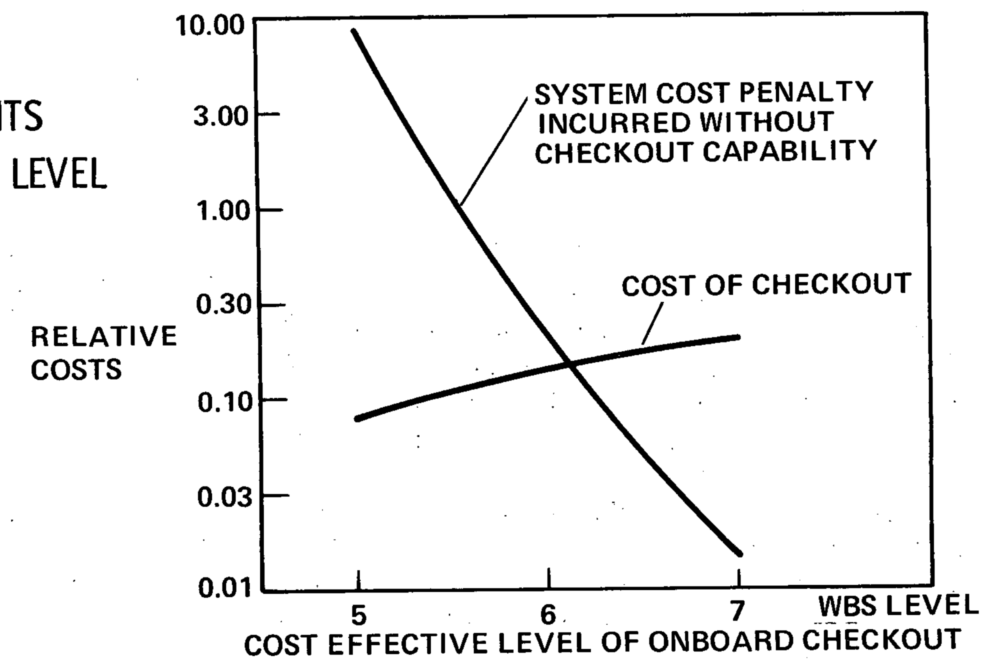
A number of importnat trade studies were conducted to establish the optimum operational configuration

The OCS uses the CDMS data processor, data distribution system, and interfacing units. It supplies a stimuli generator and C&W logic module. The C&W function is performed concurrently with, but independent of, other checkout functions.

ONBOARD CHECKOUT SYSTEM
Sortie RAM

BASIC SUBSYSTEM PARAMETERS

- MONITORING — 650 TEST POINTS
- CHECKOUT & FAULT ISOLATION — TO ASSEMBLY LEVEL
- C&W MONITOR — 35 SIGNALS



RATIONALE FOR SELECTION

- ASSEMBLY LEVEL C/O – LEAST PROGRAM COSTS
- AUTOMATED SUBSYSTEM MONITORING – MINIMUM CREW INTERVENTION WITH LEAST COST
- CENTRALIZED SIG. COND. – MINIMUM WEIGHT, POWER & COST
- USE BITE WHERE AVAILABLE – MINIMUM C/O COMPLEXITY & LOWEST COST

IMPORTANT TRADE STUDY RESULTS

- C/O & FI TO ASSEMBLY LEVEL (WBS-6)
- AUTOMATED SUBSYSTEM MONITORING – ALL OTHER OCS FUNCTIONS MANUAL
- CENTRALIZED SIGNAL CONDITIONING
- USE BITE WHERE AVAILABLE – DO NOT MODIFY EXISTING EQUIPMENT TO ADD BITE

72-1701

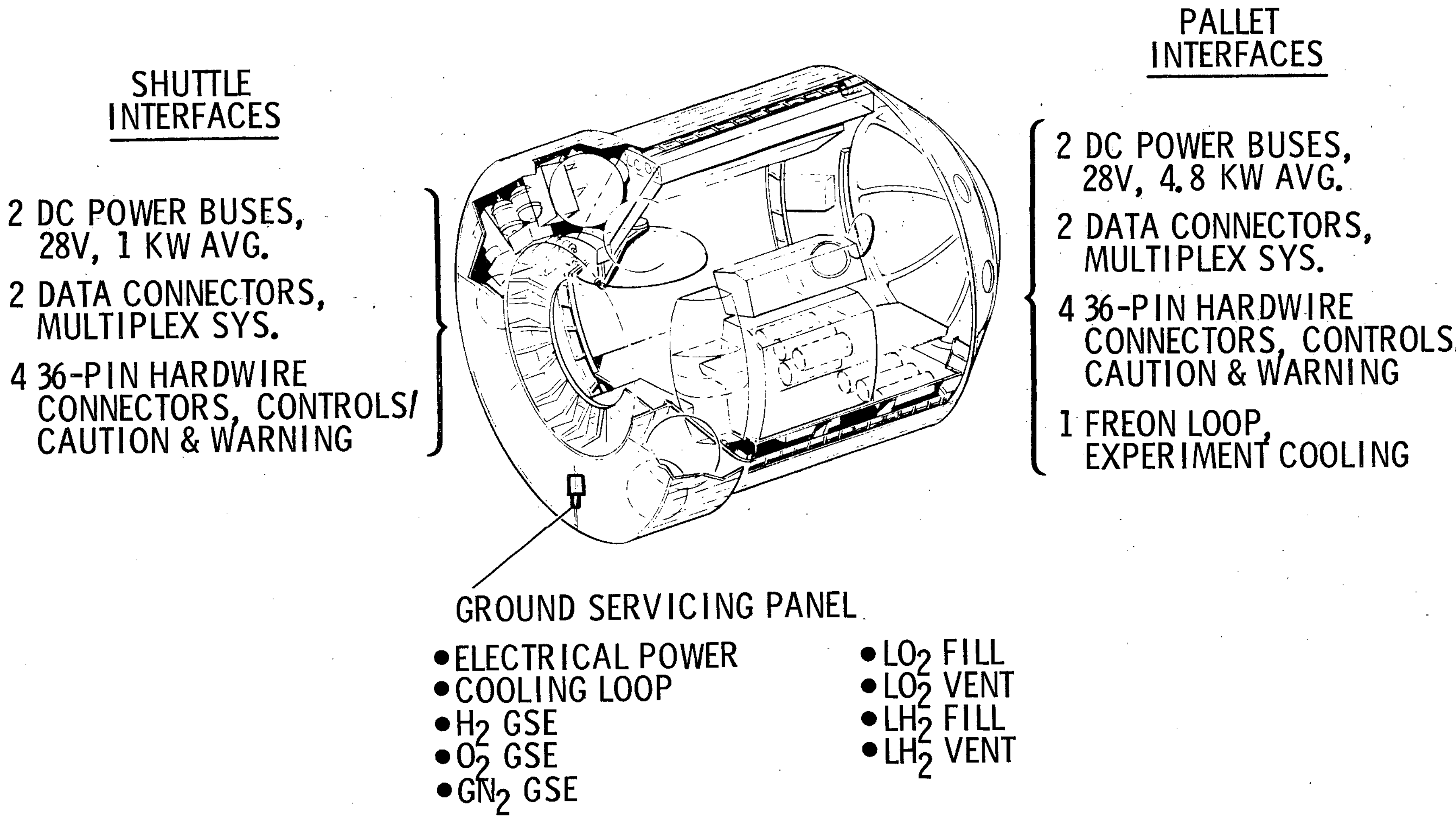
SORTIE RAM INTERFACES

The Sortie RAM has several functional interfaces with the shuttle orbiter: i.e., electrical power, data, communications, caution and warning (C&W), and controls associated with C&W. Shuttle electrical power may be used during ascent/entry and serves as a backup source during orbital operations. Redundant buses are provided. RAM relies entirely upon the orbiter for communications and data transmission to earth. This is accomplished through redundant connections to the orbiter multiplex data system. A number of redundant hardwired circuits are provided for C&W signals from RAM to the orbiter crew and for associated emergency/safety control purposes.

When a RAM Pallet is attached to the Sortie RAM, all necessary resources such as power and cooling are provided from the Sortie RAM and all data goes to it. Control functions are initiated within the pressurized volume and C&W signals are displayed therein. To accomplish these functions, redundant electrical power buses, multiplex data connectors and hardwired control/C&W signal paths are provided between the Sortie RAM and Pallet. A single Freon experiment cooling loop is provided.

A number of ground servicing functions are required by RAM while on the launch pad. Some are also used following return landing, before RAM is removed from the orbiter cargo bay and may also be used during other ground operations, as necessary. Electrical power is provided for use before the RAM and orbiter systems are started. A ground cooling loop is used to absorb RAM heat until T-5 seconds. Cryogenic oxygen and hydrogen tanks and gaseous nitrogen tanks are filled on the pad. They are also drained following landing. Gaseous makeup oxygen may be supplied to RAM on pad and excess gaseous hydrogen vented from the fuel cells. The RAM ground servicing panel is disconnected from the orbiter for RAM deployment in orbit and remotely reconnected following return to the cargo bay. The ground services are provided from GSE through an umbilical arm to a payload service panel on the side of the orbiter.

SORTIE RAM
Interfaces

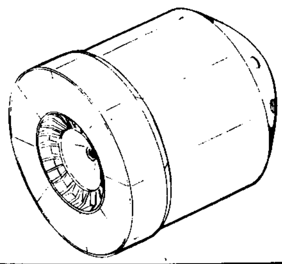


72-1693

SORTIE RAM CAPABILITY

The pressurized RAM adaptation known as sortie RAM will be available to support the earliest on-orbit experiment missions. Experiment specialist participation up to two is assumed available from the orbiter vehicle. A proportion of the RAM spacecraft pressurized volume is required for the housing of subsystems. The remainder is allocated to the housing of experiment equipment. Heat rejection capability of the sortie RAM is affected by orientation; it is best when pointing away from the earth. Electrical power consumption of the RAM subsystems varies to some degree with the electrical power consumption of the RAM payload. The fuel cell supplies up to 7 kw average of power at 28-vdc, 4.1 kw of which can be available to the user. Data is stored on magnetic tape. Communications are effected through the shuttle orbiter systems.

SORTIE RAM CAPABILITY



SUBSYSTEM PARAMETER	REQUIRED BY RAM	AVAILABLE TO USER	TOTAL
STRUCTURAL VOLUME ($FT.^3$)	910	1,040	1,950
HEAT REJECTION (1,000 BTU/HR.)	11 TO 16	UP TO 5.4	15 TO 21
LIFE SUPPORT (MAN-DAYS)	—	18	18
MISSION/EXPT. SPECIALISTS (EQUIV. MEN)	~0.2	1.8	2
ELECTRICAL ENERGY (KWH)	370 TO 440	590 (MIN.)	1,030
ELECTRICAL POWER (AVG. KW)	2.2 TO 2.8	UP TO 4.2	7
DATA STORAGE (10^9 BITS)	—	1,300	1,300
DATA TRANS (10^6 B/SEC.)	—	1.0*	1.0*
DATA PROCESSING			
-MEMORY WORDS	20,000	8,000	28,000
-TIME (mSEC./SEC.)	610	390	1,000

*VIA ORBITER

72-1753

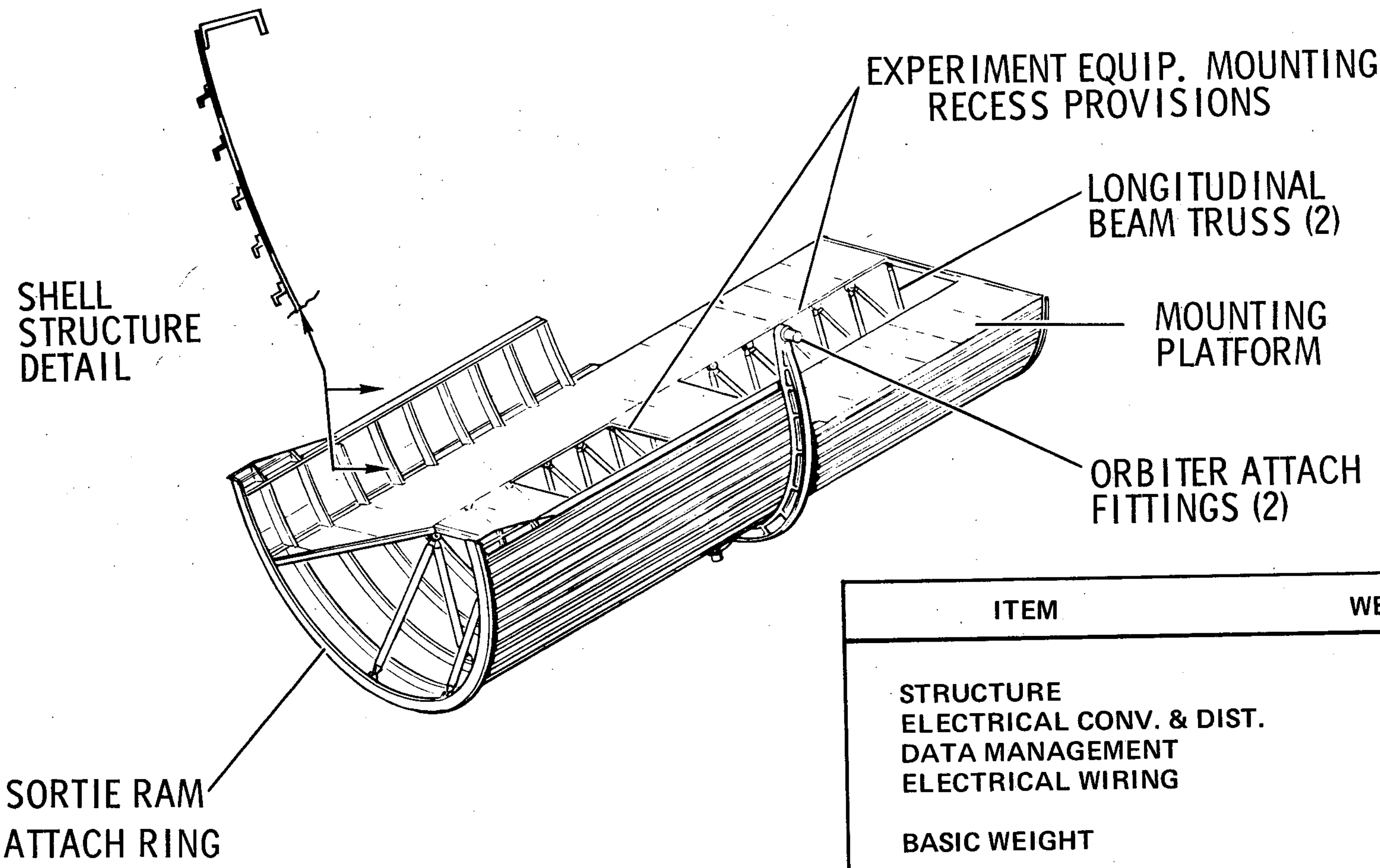
PALLET
General Arrangement

The unpressurized RAM element or pallet shown is used by attachment to either a sortie RAM or an RSM with 18-foot payload module. The design sid driven by structural rigidity requirements, payload size, viewing, and exposure requirements. It also provides utility services distribution to the external experiment payload.

The pallet structure is essentially a half cylinder made from sheet metal. It is 160 inches in diameter and 310 inches long. It has a large frame at 172 inches from the forward end. This frame is used to mount the RAM/Orbiter attach fittings. Th forward end of the pallet has a bolt ring flange that mates with a similar ring on the Sortie and RAM support modules. The structural floor runs the length of the pallet XY centerline. The side of the pallet is cut down to the floor level aft of the main frame. Two major longerons are attached to the shell structure edge at the centerline to react the large bending loads. A machined fitting is attached to these longerons at the module or forward end. These fittings serve to spread the load into the module structure and accept local moment effects on the longeron. The honeycomb structure floor is supported at the shell by other longerons and a pair of parallel and vertical beams. The lower caps of these beams also act as longerons.

Openings in the mounting platform may be covered with experiment mounting plates peculiar to each payload. A standardized pattern of mounting holes is provided on the pallet platform. This capability plus the mounting flexibility provided by the sheet/stringer construction enables the pallet to accommodate payloads with wide variations in mounting requirements.

PALLET
General Arrangement



ITEM	WEIGHT (LB.)
STRUCTURE	1,894
ELECTRICAL CONV. & DIST.	22
DATA MANAGEMENT	28
ELECTRICAL WIRING	260
BASIC WEIGHT	2,204

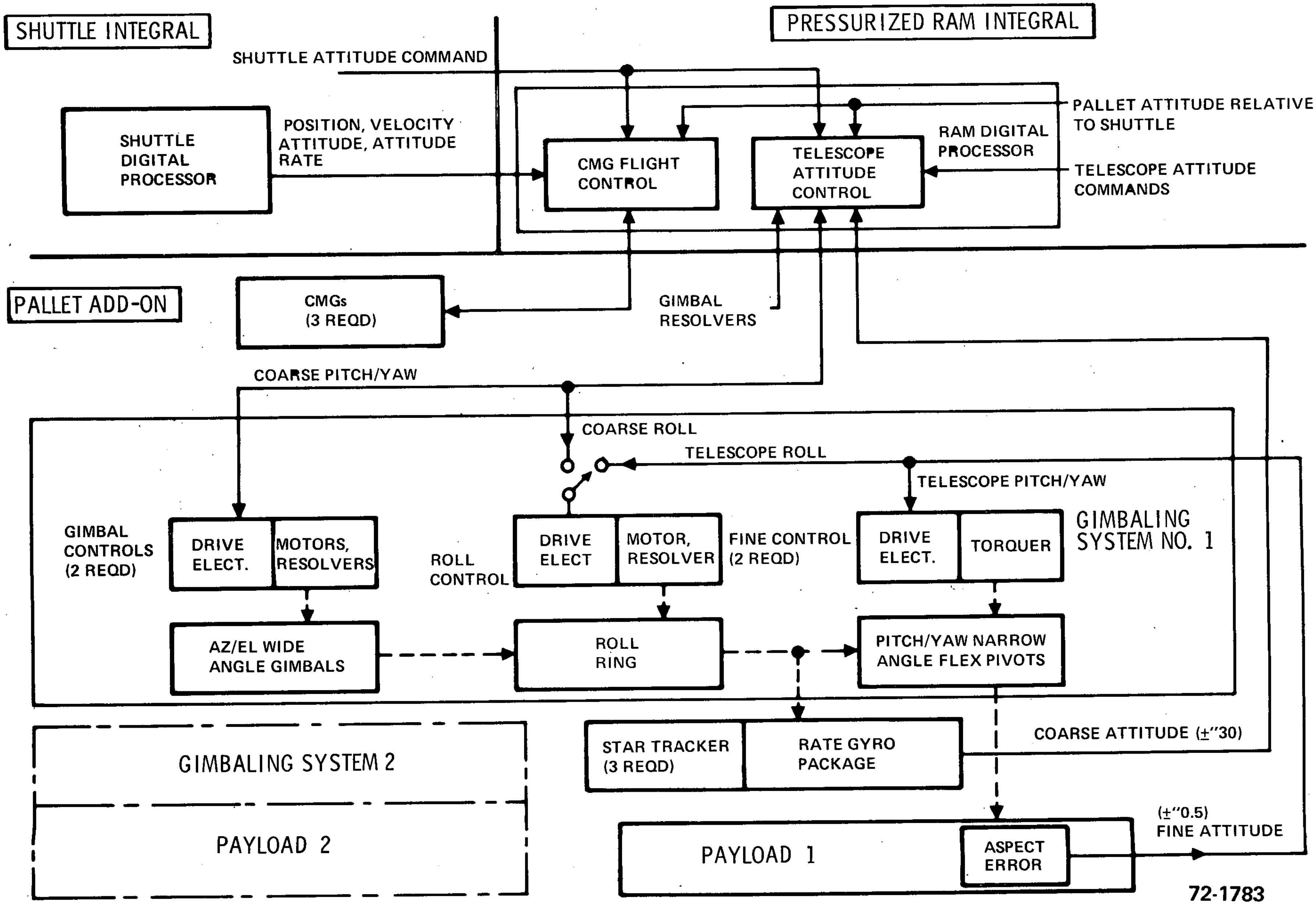
72-1675

The sortie RAM and RAM support module do not contain RAM integral GN&C provisions. However, the pallet element contains significant experiment integration equipment to augment the shuttle capability in performing sortie astronomy experiments. For these experiments, the driving requirements are maintenance of orbital environment cleanliness and all-attitude inertial pointing to 0.5 arc-sec.

Skylab type and size CMGs are provided to control the attitude of the shuttle/RAM assembly to eliminate potential contamination from the orbiter RCS and to improve base stability. Constraining the shuttle orientation to nose along the orbit normal (X-POP) yields the minimum CMG complement (three). This CMG-induced orientation constraint and the typical payload composition of two independently pointed experiments requires telescope attitude isolation. This isolation is provided by a three-axis wide-angle gimbaling system over a hemispherical range relative to the shuttle base. In addition it provides two-axis, narrow-range experiment line-of-sight fine pointing based on experiment-derived error signals. Fixed-head star trackers and a rate gyro package (same as those on the free-flying RAM) are mounted integral to each gimbaling assembly to provide attitude acquisition to 30 arc-sec.

CMG and telescope control software is implemented within a centralized RAM digital processor located in the pressurized sortie RAM or payload module (when a RAM support module is used).

GN&C SCHEMATIC
Sortie Astronomy Missions



For the astronomy payloads only the basic subsystem parameters or requirements during the design are given. With regard to pointing, the less stringent value within the range given in the table is that capability which the unaugmented shuttle will provide. The more stringent requirements are those of the most demanding astronomy experiments. Contamination requirements limit particulate density to (10^3 to 10^4 particles/meter^3 and pressure to 10^{-6} to 10^{-7} torr. These contamination or cleanliness requirements virtually exclude use of shuttle RCS control during experiment operations.

Skylab CMGs (2,300 ft.-lb.-sec. double gimbal unis) are the largest units currently available. As shown by the momentum storage and number of CMGs required, there are two viable orientations (each theoretically producing cyclic momentum storage requirements only). From these two, the shuttle X-POP orientation was chosen because of minimum CMG requirements. To support experiment polarization requirements, a wide-angle roll capability is added in addition to azimuth/elevation. The fine point vernier implementation is identical to that of Skylab. A strapdown rate gyro package is also available from Skylab. Fixed-head star trackers were selected because of commonality with the free-flying RAM.

Two identically configured gimbaling assembly sizes are provided for weight and volume conservation. The larger (113-inch yoke, 2,474 lb., 233 watts) is constrained in size by the shuttle bay/pallet available volume during launch. The smaller (76-inch yoke, 1,374 lb., 148 watts) conserves weight and volume and accommodates about 65% of the astronomy experiments.

GN&C SUBSYSTEM
Sortie Mission*

BASIC SUBSYSTEM PARAMETERS

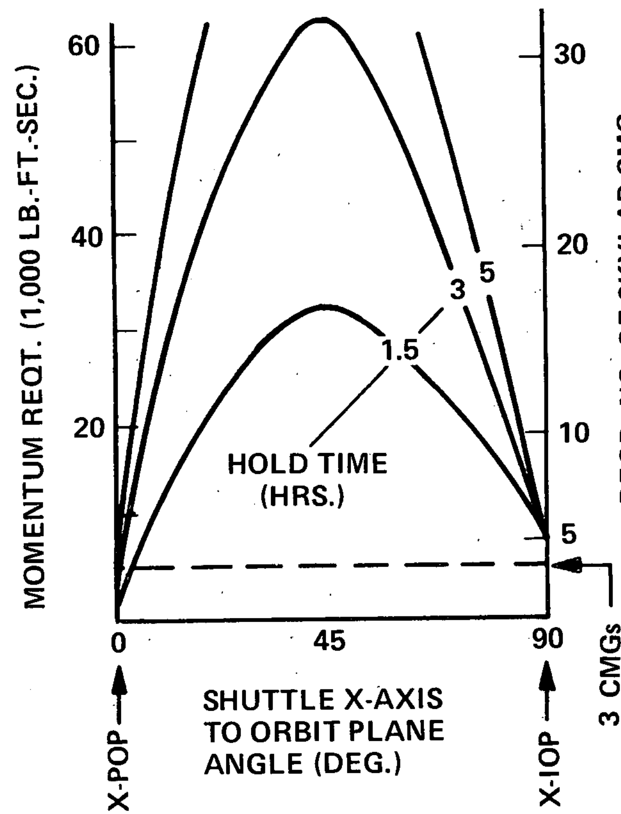
- ORIENTATION — INERTIAL
- POINTING AUGMENTATION

ACCURACY	±(0.5° - 1 ARC-SEC.)
STABILITY	±(0.5° - 0.5 ARC-SEC.)
ACQUISITION	±(0.25° - 30 ARC-SEC.)

- CONTAMINATION — NON-RCS CONTROL PREFERRED

RATIONALE FOR SELECTION

- 3-AXIS WIDE-ANGLE GIMBAL — CMG CONTROL CONSTRAINS SHUTTLE ORIENTATION
- 2-AXIS NARROW-ANGLE FINE POINT GIMBAL — DERIVED FROM SKYLAB
- STAR TRACKER/RATE GYRO PACKAGE — AUTONOMOUS PALLET ATTITUDE REFERENCE



IMPORTANT TRADE STUDY RESULTS

- SHUTTLE X-POP ORIENTATION SELECTED BECAUSE MINIMUM NUMBER OF CMGs RESULTS
- FOR WEIGHT & VOLUME REQUIREMENT REDUCTION, RECOMMEND TWO GIMBALING ASSEMBLY SIZES

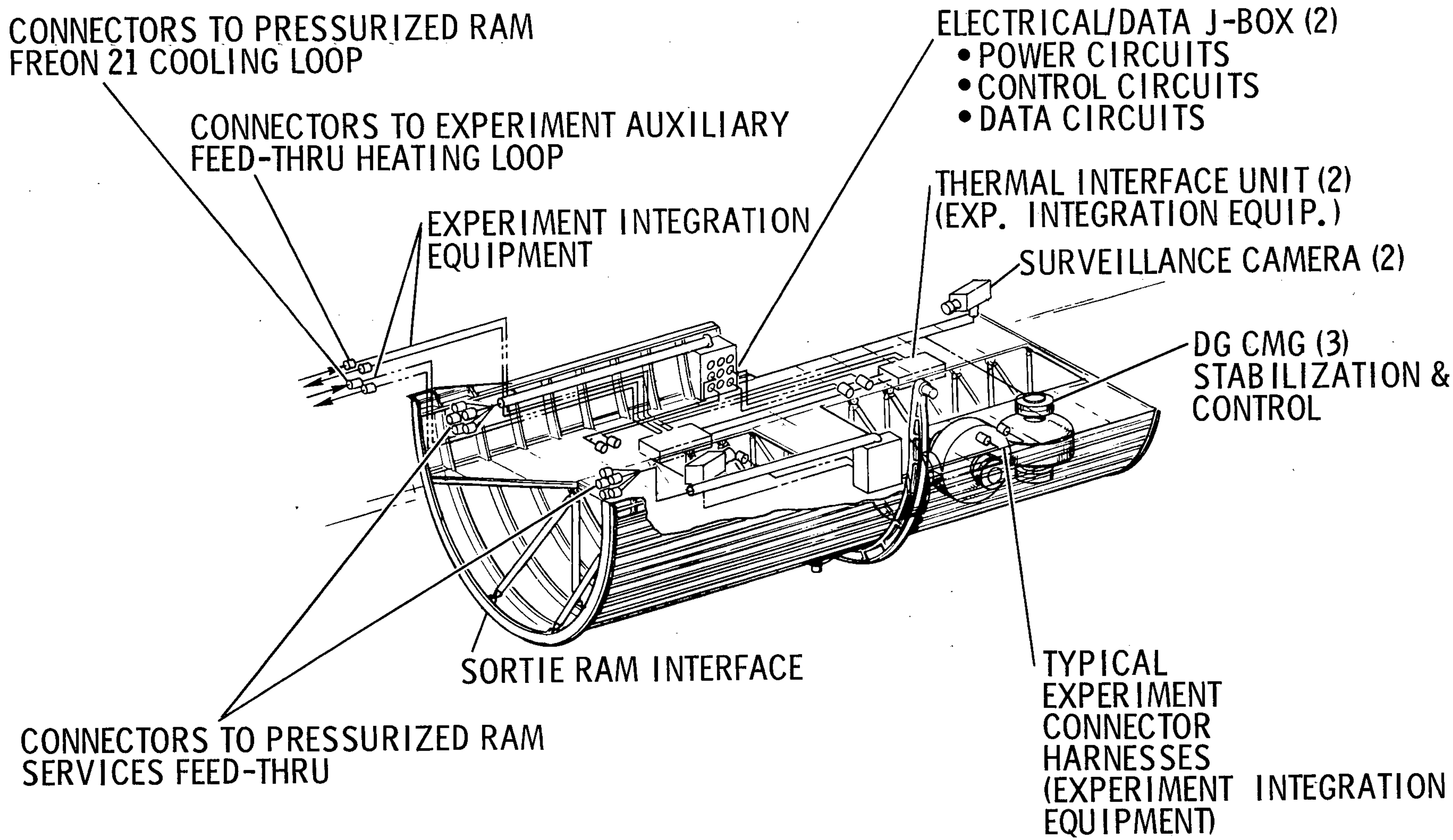
*EXPERIMENT INTEGRATION EQUIPMENT FOR ASTRONOMY ONLY. FOR OTHER EXPERIMENTS, SHUTTLE OR EXPERIMENT PROVIDES.

72-1808

PALLET SUBSYSTEM INSTALLATION

Subsystems and experiment integration equipment for the pallet are shown. The electric power subsystem is limited to distribution, since the prime power source is either the sortie RAM or RSM. Floodlights are provided as required for experiment operations. The data management system consists of 5 DIU to handle low data rate signals that command and monitor experiment and GN&C equipment. For sortie astronomy paylaods, three Skylab type and size CMGs are added to provide observation and stability accuracies required without the contamination associated with shuttle RCS firing. For thermal control of pallet-mounted equipment, the basic system of the sortie RAM or payload module is used with Freon cold plates located on the pallet.

PALLET SUBSYSTEM INSTALLATION



72-1682

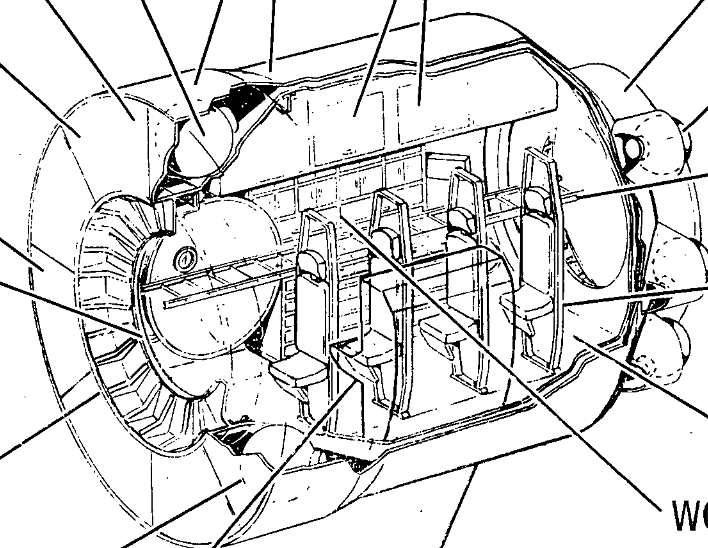
RAM SUPPORT MODULE
General Arrangement

The RAM support module is designed to support a significant range of experiment payloads. The interior above-floor arrangement consists primarily of a control and display console for subsystems and experiments, and habitability provisions for up to four payload specialists. The integrated control and display console is located at the forward end relative to the orbiter. Subsystem components and assemblies mounted within the pressurized volume are located at the module forward end and beneath the floor. Subsequent charts give details. The internal arrangement is designed for ease of crew movement and access to equipment.

A forward external equipment bay, covered with a circumferential three-foot wide radiator extends aft from the orbiter interface plane. Diameter across the radiator is 15 feet, the maximum envelope allowed in the cargo bay of the orbiter. Located in the equipment bay are two LO_2 tanks, three LH_2 tanks, a single fuel cell, fuel cell ancillary equipment, thermal control subsystem assemblies, and a ground disconnect panel for ground services. The forward conical transition section is pierced four places with feedthroughs for fuel cell cabling and external control and monitor circuits, water plumbing, gaseous O_2 and N_2 and the cabin atmosphere relief and vent valve.

A 102-inch diameter aft ,aaft mating structure provides for RAM payload module attachment. The 45-deg. conical bulkhead that joins this structure to the pressure shell provides clearance for seven GN_2 bottles used for RAM payload module repressurization when required.

RAM SUPPORT MODULE
General Arrangement



ITEM	WEIGHT (LB.)
STRUCTURE	5,318
SUBSYSTEMS	5,781
TOTAL (DRY)	11,099
CREW (4) & CREW EQUIP.	1,295
RESIDUALS, RESERVES & EXP. (MAX.)	2,618
TOTAL	15,012

72-1716

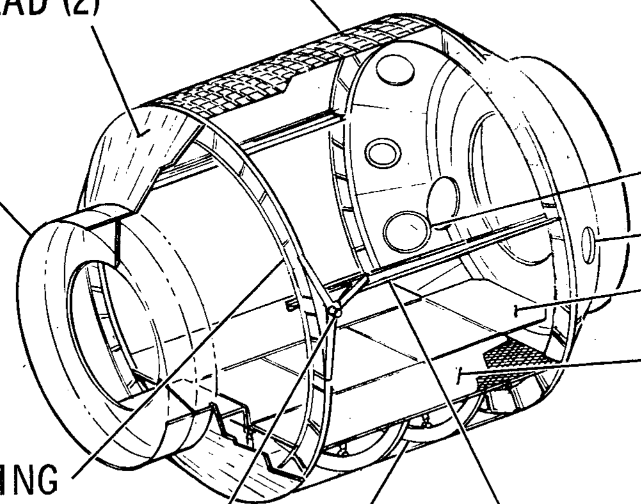
RAM SUPPORT MODULE STRUCTURE

The RAM support module structure provides support for the subsystems and containment of a livable atmosphere so that experiments may be monitored and equipment maintained within a shirtsleeve environment. The structure must hold internal pressure and react external forces due to boost and maneuvering loads imposed by the orbiter and by docking procedures. The structure also provides sleeping quarters and seats for a four-man crew.

The structure is made up of the pressure shell, which consists of cylindrical walls, bulkhead, and docking adapters. It also consists of the environmental protection system, the RAM/orbiter support system, and secondary structure that includes internal floors, and internal and external equipment.

The structure is basically a cylindrical shell with conical bulkheads. It has a maximum internal diameter of 160 inches and a diameter over the cylindrical section of 14 feet. The maximum diameter of the module is 15 feet (over the forward radiator). The total internal volume is 1,890 feet.

RAM SUPPORT MODULE STRUCTURE



MATERIAL NOTES

WELDED PRESSURE SHELL 2219-T851 Al
SECONDARY STRUCTURE 2024-T3 Al
RAM ORBITER FITTINGS 4340 STEEL

ITEM	WEIGHT (LB)
PRESSURE SHELL	755
BULKHEADS	1,020
REINFORCING ATTACH. MEMBERS	1,048
ORBITER ATTACH. & BACKUP	752
FLOORS	361
BASIC WT.	3,936
RADIATOR/METEOROID PROTECTION & INSULATION (NOT SHOWN)	1,382
TOTAL	5,318

72-1820

RAM SUPPORT MODULE STRUCTURE

Details

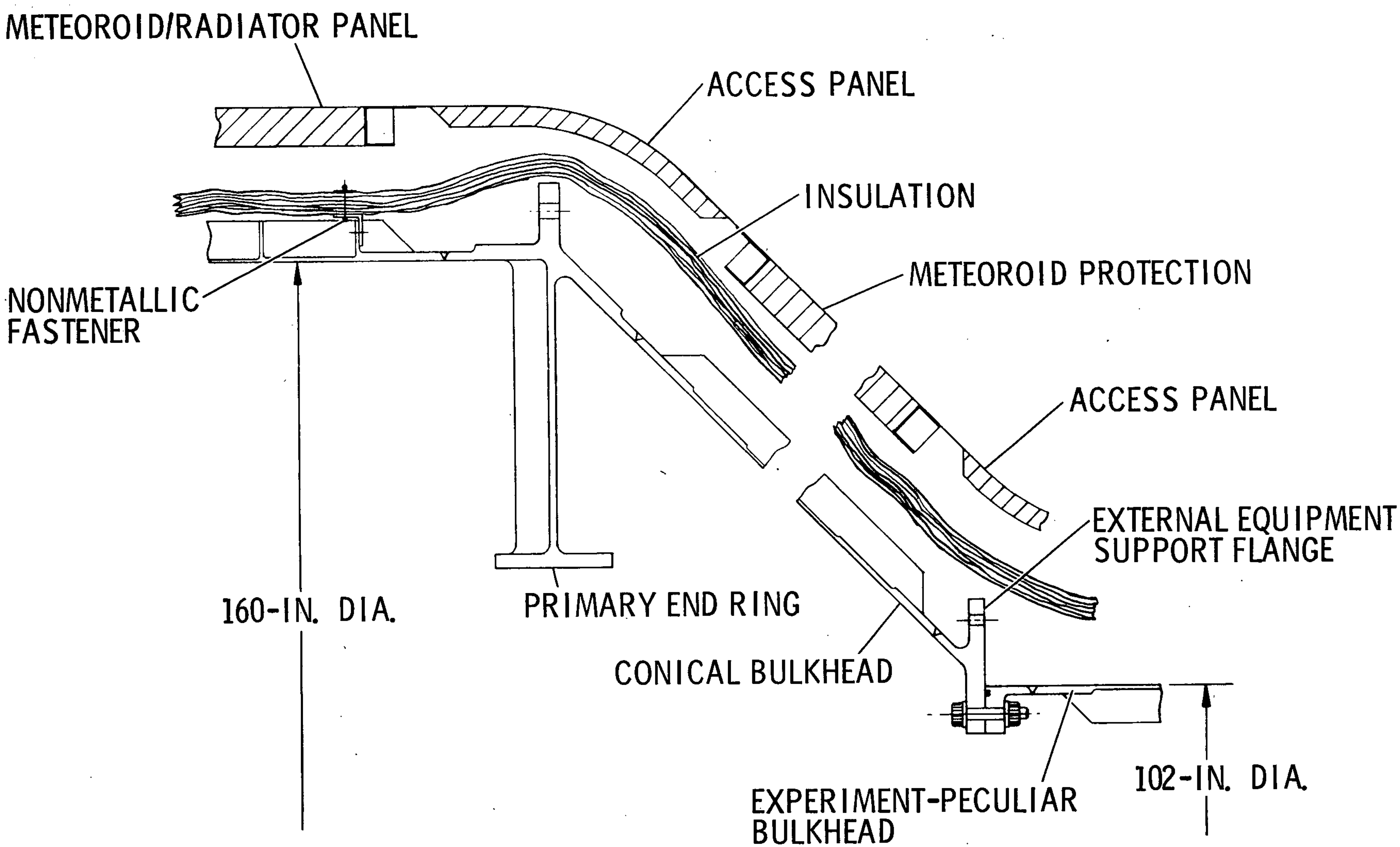
The RAM support module has an identical structure with the sortie RAM using the same 160-inch diameter cylindrical section and identical 45-deg. conical bulkheads. It also uses the 102-inch diameter by 8-inch long adapter and two MDAC docking adapters. The differences between the sortie RAM and the RAM support module are in the interior structure, the orbiter attachment fitting, and in the substitution of a mating adapter for a closure bulkhead.

The RAM support module has an identical floor structure with the sortie RAM, as well as the three utility tunnels in the ceiling area. It can have up to four sleep compartments and personal storage areas. These compartments are made from sheet metal and honeycomb panels that are attached to the edge members and drag angles of the utility tunnels.

Because the RAM support module is never used in the orbiter without another module or a pallet, the RAM/orbiter attachment fittings are not installed on the aft structural ring.

The radiator/meteoroid bumper design used on the RAM support modules is identical with that on the sortie RAM, except for the shroud panels covering the GN_2 bottles and the aft docking adapter.

RAM SUPPORT MODULE STRUCTURE
Details



72-1761

The pressure wall thickness of the cylindrical sidewall was selected on the basis of manufacturing minimums and because it is an optimum design (minimum structure weight) for the waffle structure. At these thicknesses the operating stresses are low, yielding high critical crack lengths.

For commonality all meteoroid bumpers have been standardized. The primary bumper is 0.016 inch and the secondary bumper is 0.010 inch thick. The function of the secondary bumper is to protect the insulation from fragments resulting from meteoroid penetration of the primary bumper. The insulation selected is Superfloc which is kept in place by means of nonmetallic fasteners, such as Teflon or nylon, to minimize heat shorts. These were determined by the penetration probability requirements, the surface area of the largest pressurized module, and by the longest RAM mission.

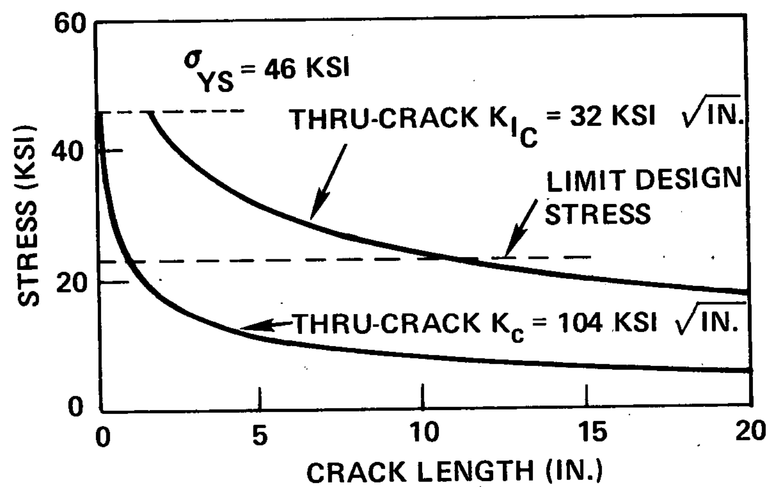
The five-point RAM/orbiter attachment fitting concept was derived from the requirement of static determinacy. One implication of this requirement is that the longitudinal loads are reacted at one location; this load results in a large couple or moment induced into the module sidewall. An internal beam structure was selected for this task as it yields the lowest weight system, is the best from manufacturing considerations and – most important – neither cuts through the radiator system nor induces thermal shorts into the basic module structure.

Data developed in this study shows that 2219-T851 aluminum alloy is the best material for the components of the pressurized RAM module. It was selected on the basis of its excellent corrosion resistance, fracture toughness, weldability, and machinability.

STRUCTURAL SUBSYSTEM
RAM Support Module

BASIC SUBSYSTEM PARAMETERS

- 0.070-IN. PRESSURE SHELL THICKNESS
- 0.016-IN. METEOROID BUMPER
- 0.010-IN SECONDARY BUMPER
- FIVE-POINT RAM/ORBITER ATTACHMENT
- INTERNAL BEAMS FOR ORBITER ATTACH FITTINGS
- 2219 ALUMINUM ALLOY



RATIONALE FOR SELECTION

- MANUFACTURING MINIMUMS
- P_0 = 0.995 FOR 1.0 YEAR
- BY STATIC DETERMINACY
- PROTECTION OF INSULATION
- TO REDUCE HEAT SHORTS & NOT REDUCE RADIATOR AREA
- WELDABILITY, FRACTURE TOUGHNESS & CORROSION RESISTANCE

IMPORTANT TRADE STUDY RESULTS

- SIDEWALL STIFFENING REQUIREMENTS MINIMAL WITH 0.070-IN. SKIN THICKNESS
- WAFFLE GRID SIDEWALL - LIGHTEST
- LONG LIFE CONSIDERATIONS - NOT CRITICAL

72-1797

THERMAL CONTROL SUBSYSTEM
RAM Support Module

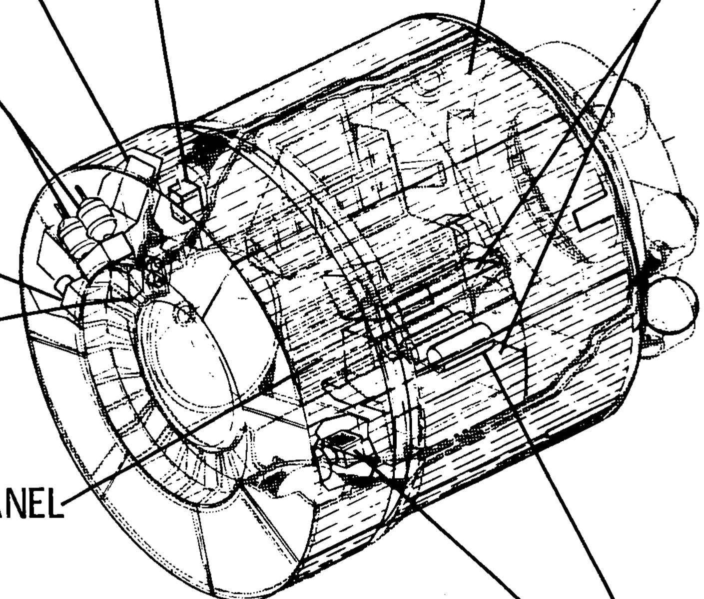
The thermal control subsystem uses a dual-fluid concept. Water is used in the habitable areas to avoid toxicity and flammability hazards. Freon 21 is used in the radiator circuit since the radiator temperature can be well below the freezing point for water in some cases.

A bypass valve around the radiator regulates the Freon temperature to 35F and provides control for variations in internal and external loads. There are two completely independent systems in the radiator field over the main hull, each system is capable of carrying the entire cooling load, thereby providing redundancy in event of component failure. The radiator field over the external equipment bay does not contain the redundant cooling loop.

For closed shuttle door operation and transient peak heating periods, a water sublimator and thermal storage element are provided. An interface heat exchanger receiving coolant from ground support equipment is used during prelaunch and postlanding. The TCS interfaces with EC/LS at air-to-liquid heat exchangers where cabin sensible and latent loads are absorbed by the TCS. In addition, the Freon loop is used to warm the cabin oxygen supply.

Provisions are made for additional use of radiator panels on the attached payload module.

THERMAL CONTROL SUBSYSTEM
Ram Support Module



ITEM	WEIGHT (LB.)
PUMPS & ACCUMULATORS	63
HEAT EXCHANGERS	291
WATER SUBLIMATOR	136
HEAT STORAGE ELEMENTS	300
PLUMBING VALVES & MISC.	200
RADIATORS	(1,382)*
TOTAL (DRY)	990
FLUIDS	513
TOTAL	1,503

* RADIATOR (INDUCED ENVIRONMENTAL PROTECTION) WEIGHT ASSIGNED AS PART OF STRUCTURAL WEIGHT

72-1826

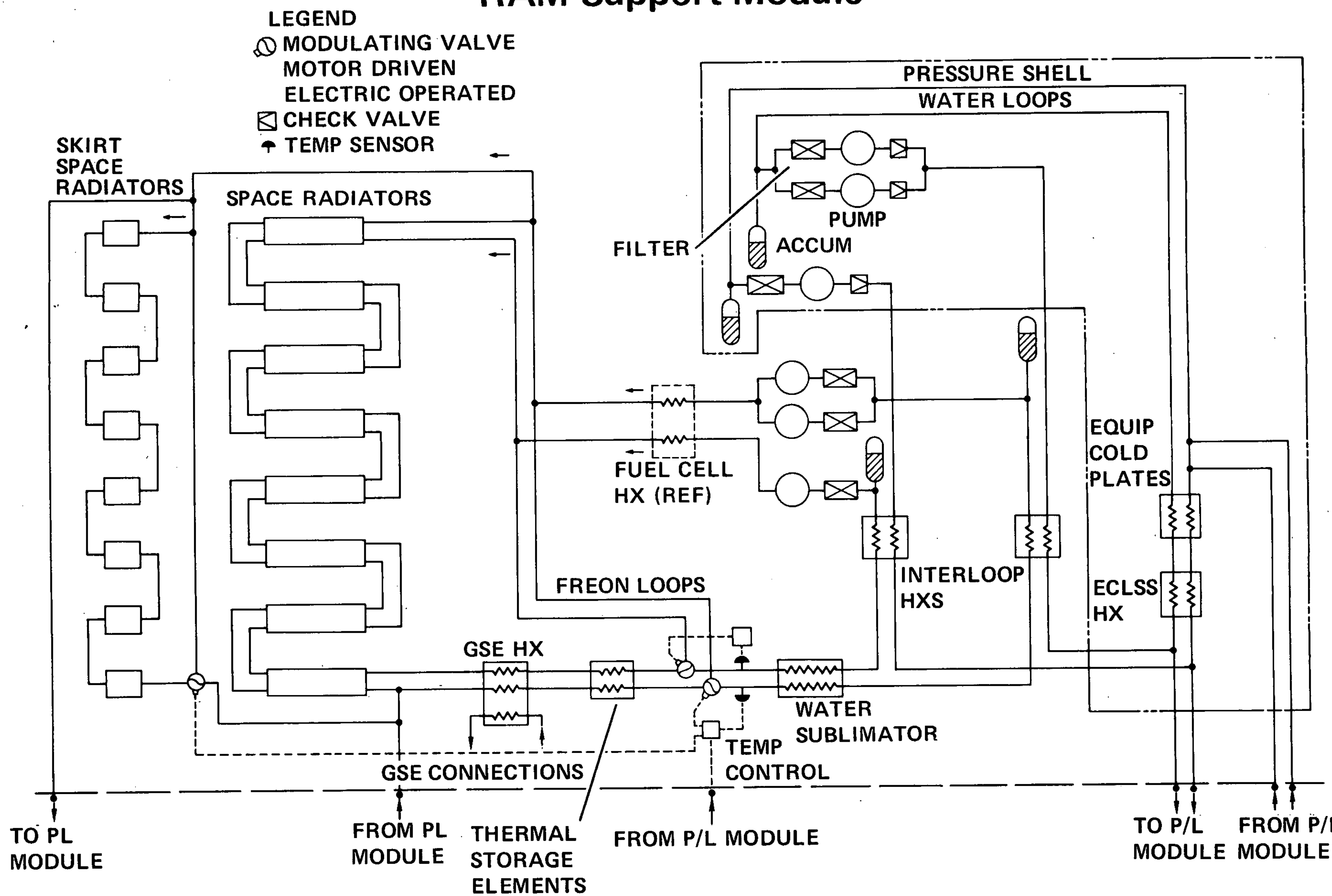
THERMAL CONTROL SUBSYSTEM SCHEMATIC
RAM Support Module

The Sortie RAM thermal control subsystem consists of two fluid systems. Water is used in the habitable compartment because of safety and excellent heat transfer capability. The water transfers heat from all the interior heat sources to an external Freon 21 system across an interloop heat exchanger. This heat and also heat rejected by the fuel cell are transferred to the radiator panels and rejected to space. The Freon supply temperature to the intercooler is maintained at a nominal value of 35F by a radiator bypass control. Thermal damping during periods of rapid transients or peaking loads is provided by the thermal storage element. This element is sized for the re-entry condition when neither the radiators nor the sublimator can be used. The sublimator is used for on-orbit cooling during periods when the cargo bay doors are closed. Redundancy is provided in both loops, except for the skirt radiators, by using two independent circuits for each loop.

The subsystem interfaces with a ground coolant supply through the GSE heat exchanger. This arrangement supplies cooling during prelaunch and postlanding operational phases.

The subsystem also interfaces with the environmental control life support subsystem (EC/LS) through the EC/LS heat exchanger. Because this heat exchanger is a condensing heat exchanger to provide control, this demand fixes the minimum fluid temperature requriements, resulting in the Freon design control point of 35F. Both the water and Freon loops interface with the Payload Module to provide thermal control for that RAM element.

THERMAL CONTROL SUBSYSTEM SCHEMATIC
RAM Support Module



72-1768

THERMAL CONTROL SUBSYSTEM
Ram Support Module

The basic subsystem parameters shown were based on plus-three-sigma heating for the space radiators and shuttle equipment performance for the sublimator. The thermal storage element was sized for 1.5 hours of operation, which includes a 30-minute postlanding period before GSE hookup. A phase change material with heat of fusion of about 90 Btu/lb. was assumed. The radiator area is that available using the sidewall area plus a three-foot skirt extension.

The methods of heat rejection and thermal control were compared and selection based on weight, cost and system complexity. Radiators were selected because the weight of sublimed expendables for the loads anticipated over a seven-day mission would be prohibitive. The sublimator was selected for use on-orbit when the cargo bay doors are closed. Excess water is available from the fuel cell for this unit and the selected component is common with shuttle equipment.

The thermal storage element provides passive control when neither the sublimator nor radiators are usable. Since the functioning of the unit is automatic and requires no moving parts, minimum system complexity results.

The radiator coating selection was based primarily on comparison of the Teflon/Ag/Inconel second-surface mirrors with Z-93 white paint. Radiator panel bypass valves would be required using the paint and a more complex temperature control technique would be required. Use of the second surface mirror eliminates the panel valving requirement.

A comparison of the effect of using plus-three-sigma heating and nominal space heating values for radiator performance was made. As shown, approximately 20% more heat rejection capability is obtained at a given cabin temperature using the nominal case. It is also shown that selection of cabin air temperatures and/or radiator orientation significantly affects heat rejection capability.

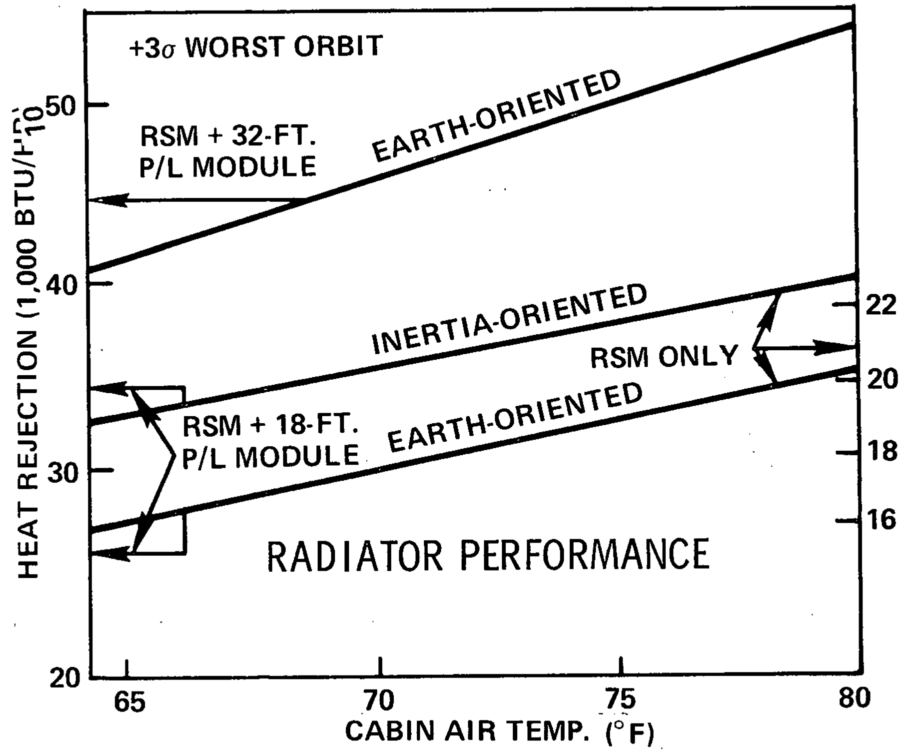
THERMAL CONTROL SUBSYSTEM
RAM Support Module

<u>BASIC SUBSYSTEM PARAMETERS</u>

- FREON TEMPERATURE CONTROLLED TO 35°F
- RADIATOR HEAT REJECTION (BTU/HR.)
  - INERTIAL ORIENTATION: 19,600
  - RAM TOWARD EARTH: 16,150
  - RAM AWAY FROM EARTH: 20,700
- SUBLIMATOR HEAT REJECTION: 74,000 BTU/HR
- THERMAL STORAGE: 13,900 BTU
- RADIATOR AREA: 531 FT.^{2}

<u>SELECTION RATIONALE</u>

- RADIATORS - LOWEST ON-ORBIT WEIGHT
- SUBLIMATOR - FUEL CELL WATER AVAILABLE
- THERMAL STORAGE - SIMPLICITY
- CONTROL TEMPERATURE - HUMIDITY



RADIATOR PERFORMANCE

<u>TRADE STUDY RESULTS</u>

- RADIATORS FOR ON-ORBIT HEAT REJECTION DOORS OPEN
- SUBLIMATOR FOR ON-ORBIT HEAT REJECTION, DOORS CLOSED
- THERMAL STORAGE FOR IN-ATMOSPHERE TEMPERATURE CONTROL
- USE SECOND-SURFACE MIRROR FOR RADIATOR COATING (α = 0.09, ϵ = 0.8)

72-1767

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM

RAM Support Module

The RAM support module contains an independent EC/LS configured to meet the requirements pertaining to atmosphere storage, atmosphere revitalization and distribution, water management, cabin pressure control, and special life support. Primary control and display of EC/LS functionability and status is located on the C&D console with second-level control and display located at the secondary control panel.

ATMOSPHERE CONDITIONING – the primary processing components that are necessary to revitalize and maintain the RSM and attached payload module atmosphere within design limits are located under the floor. A filter and debris trap removes atmosphere particulate matter and is replaced when the pressure drop indicates a loaded filter. Downstream of the filter, two fans in parallel provide the atmosphere circulation. Only one fan operates at a time. Lithium hydroxide is used for CO_2 removal and activated charcoal for odor and trace gas removal. A condensing heat exchanger provides humidity control. The condensate is pumped to storage tanks. Revitalized cabin atmosphere flows through a distributing duct network. Air passing through the condensing heat exchanger is bypass-controlled to maintain the cabin temperature between 65 and 85F.

PRESSURE CONTROL – a pressure control assembly maintains cabin pressure at 14.7 psia, supplies GO_2 and GN_2 for repressurization and emergency use, and supplies O_2 gas to the cyclic accumulators and N_2 gas to the water storage tanks.

The cabin pressure is maintained at 14.7 psia by controlling the O_2 partial pressure between 3.0 and 3.4 psia and supplying N_2 gas to make up the balance.

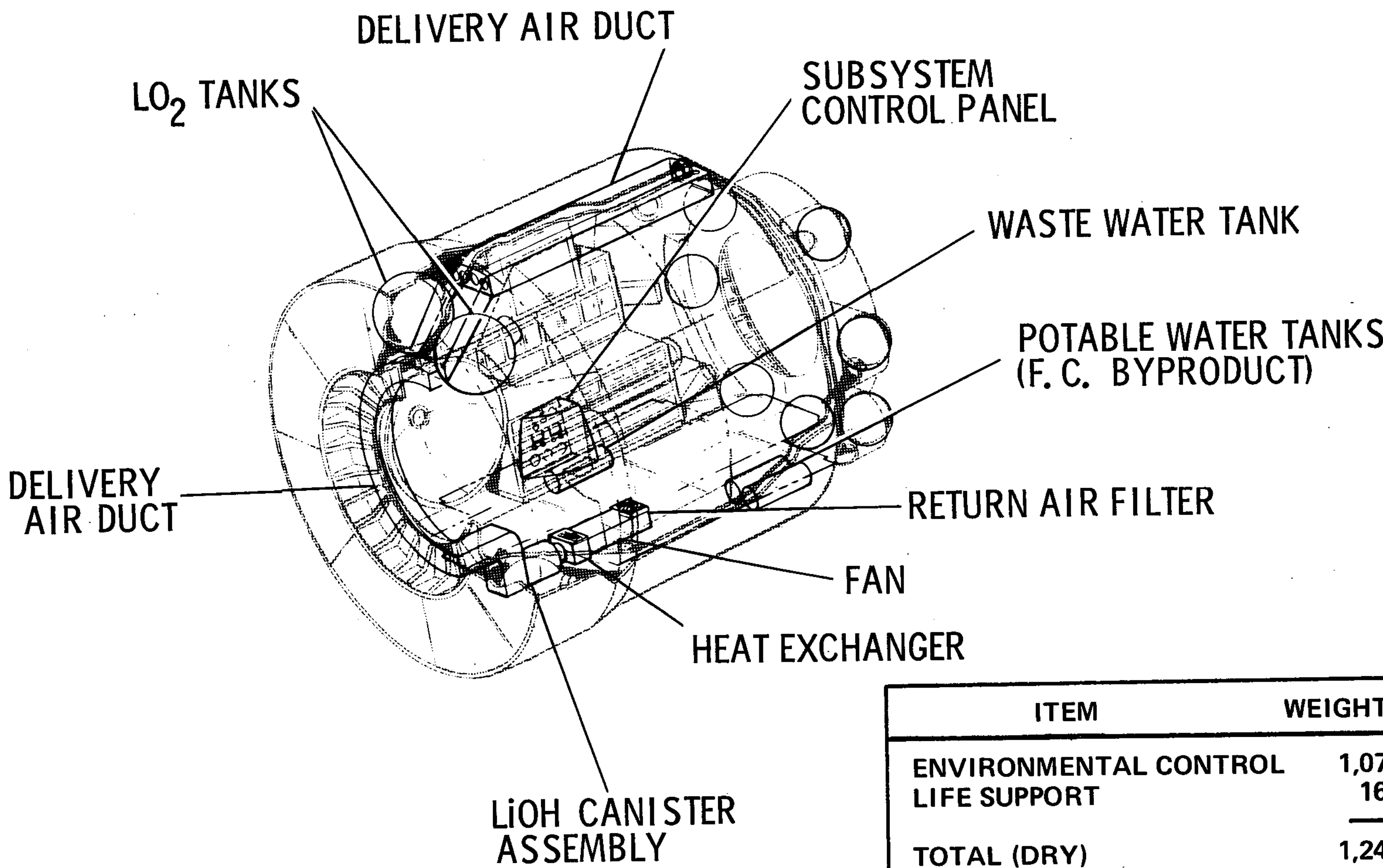
WATER MANAGEMENT – a water management assembly provides for RAM water needs, prevents bacterial buildup provides storage of fuel cell generated water and condensate from humidity removal unit(s) and supplies water for the sublimator in the TCS. Fuel cell water passes through an H_2 separator and silver ion resin bed for sterilization.

SPECIAL LIFE SUPPORT – two subassemblies provide emergency functions of fire detection and IVA support. acquisition and command distribution system and a centralized computer configuration with floating-point Connections for six IVA umbilicals are provided.

GASEOUS STORAGE – oxygen storage is integrated with the EPS reactant storage. Nitrogen is stored at 3100 psia in titanium tanks located at the aft end of the RSM externally.

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM

Ram Support Module



ITEM	WEIGHT (LB.)
ENVIRONMENTAL CONTROL	1,077
LIFE SUPPORT	166
TOTAL (DRY)	1,243
EXPENDABLES (MAX.)	913
TOTAL	2,156

72-1821

EC/LS SCHEMATIC
RAM Support Module

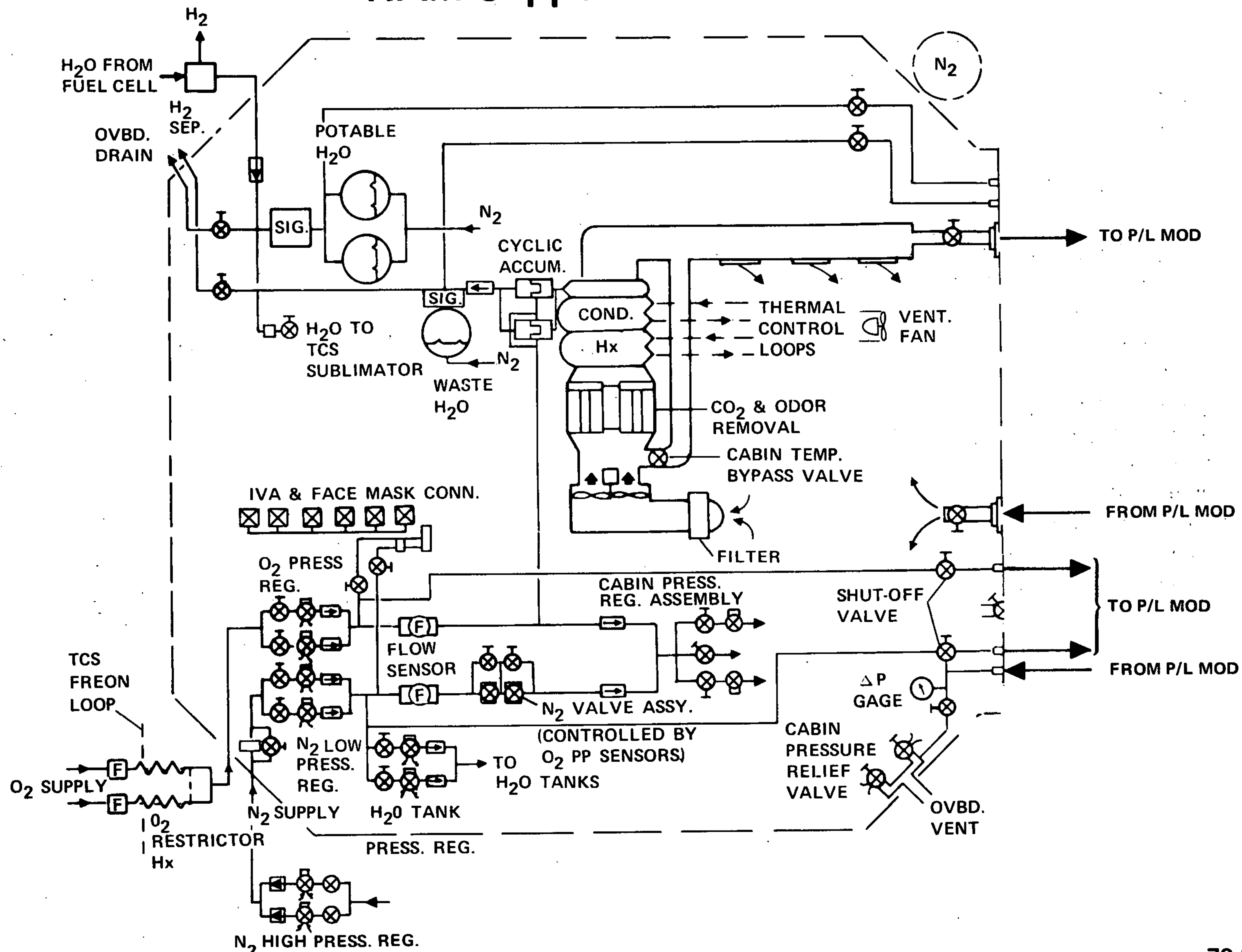
The RAM Support Module environmental control and life support subsystem provides atmospheric control within the module and support up to six payload specialists. The system is completely independent from the shuttle except that lithium hydroxide (LiOH) canisters for CO_2 control are stored in the shuttle. The subsystem provides cabin pressure control and maintains oxygen partial pressure. Condensing heat exchangers absorb heat picked up by the cabin air and control the humidity level in the compartment. CO_2 and odors are removed by LiOH and activated charcoal canisters.

All fuel cell water and humidity condensate water collected during the mission is stored in onboard tankage. Water generated by the fuel cell flows through a hydrogen gas separator which is located externally to the pressurized volume. Before entering the tanks, the condensate passes through a silver ion generator (SIG) to kill micro-organisms that may have entered the water system. In the water line to the sublimator, a filter removes any particles that may be in the water.

Facilities for contingency repressurization and IVA and face mask support are provided. Connections for six IVA umbilicals exist in the RAM support module. Support is limited to purge flow of oxygen and nitrogen to the IVA suits in the event of contingency depressurized or contaminated cabin operations.

The flood flow rate must be maintained at a minimum of about eight pounds per hour to prevent the buildup of heat and the possible collapse of the man from heat prostration. The EC/LS subsystem can provide pure oxygen at this rate for four payload specialists and can accommodate six payload specialists with a 2/3 oxygen and 1/3 nitrogen mixture for a nominal 8-psia suit pressure.

ENVIRONMENTAL CONTROL/LIFE SUPPORT SCHEMATIC
RAM Support Module



72-1780

The RAM support module environmental control and life support subsystem (EC/LS) provides for atmospheric storage, water management, atmospheric revitalization, pressure control, fire detection and IVA and face mask support for up to six payload specialists. The system is completely independent of the shuttle vehicle except that lithium hydroxide/charcoal canisters for Co_2 and odor control for two men for seven days are contained in the shuttle stores. The additional canisters are stored in the RSM.

A two-gas pressure system controls nitrogen flow to maintain a compartment pressure of 14.7 psia in both the RSM and payload module while maintaining an oxygen partial pressure at a nominal value of 3.1 psi. A condensing heat exchanger is used to extract heat and moisture in the air to maintain a temperature of 65 to 85F, as selected and to control the relative humidity. The humidity condensate is collected from the heat exchanger and periodically transferred to a waste water storage system sized to store all water collected during the mission including that from the payload module. In addition to waste water storage, all fuel cell water generated during the mission is stored in sterile condition in a separate water storage system. This water is available as required by the sublimator in the thermal control subsystem. All tanks are pressurized to 20 psia with nitrogen which permits transfer of the fuel cell water to the sublimator.

High-pressure nitrogen gas storage is used. Storage capacity is adequate to provide make-up for leakage in the RSM and payload module and to repressurize both vehicles to 11.6 psi partial pressure one time should decompression occur. The oxygen is contained in the fuel cell reactant cryo tankage and is sufficient to provide leakage make-up for both modules, metabolic needs, repressurization of both vehicles to 3.1 psi partial pressure once, and IVA support for six men for six hours. Contaminant control is provided by particulate filter, activated charcoal and lithium hydroxide which neutralize or eliminate the major identifiable contaminants. The build-up of metabolically produced carbon monoxide was analyzed and found to be well within the acceptable physiological limit of 29 milligrams per cubic meter for a mission duration of 30 days for four payload specialists in an RSM with a payload module having a total volume of 5,650 cu.ft. Six payload specialists could be accommodated in the same modules for a period of 29 days before the CO concentration reached the designated limit.

The following is a summary of the significant trade studies conducted.

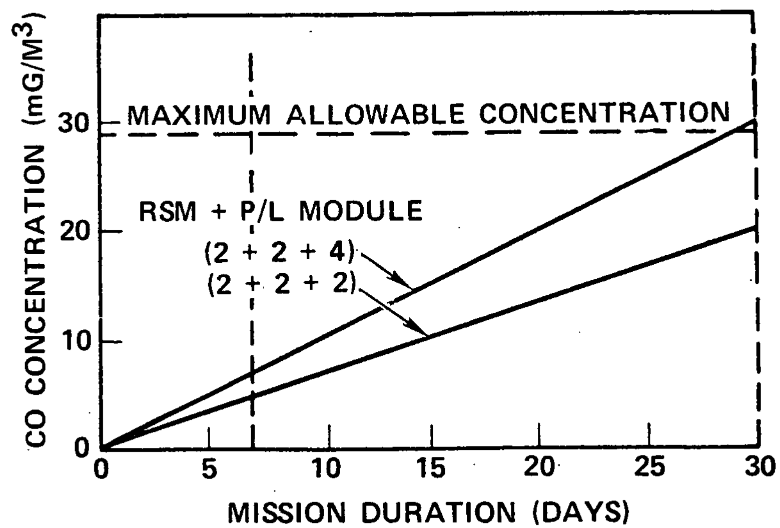
NITROGEN STORAGE – High-pressure gas storage ws compared with supercritical cryogenic storage. High- pressure storage was lighter and cost less than cryogenic storage for the gas storage requirements considered.

OXYGEN STORAGE – High-pressure gas storage was compared with supercritical cryogenic storage. Since the fuel cell reactants were already stored supercritically, it was advantageous to include the EC/LS oxygen with the fuel cell oxygen.

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM
RAM Support Module

BASIC SUBSYSTEM PARAMETERS

•PRESSURE CONTROL (NOM.)	14.7 PSIA
•OXYGEN PARTIAL PRESS.	3.1 PSI
•CO_2 PARTIAL PRESS. (NOM.)	3.0 MM Hg
•H_2O PARTIAL PRESS.	6-13 MM Hg
•AIR TEMP. SELECTABLE	65-85 F
•BULK AIR VENTILATION VEL.	20-50 FPM
•WASTE WATER STORAGE	187 LB.
•FUEL CELL WATER STORAGE	875 LB.
•SIX-MAN IVA CAPABILITY	



SELECTION RATIONALE

- •TWO-GAS PRESS. CONTROL — SHUTTLE COMMONALITY
- •LiOH/CHARCOAL, CO_2 & ODOR CONTROL — SIMPLE, DEVELOPED
- •CONDENSING HEAT EXCHANGER — HUMIDITY CONTROL
- •SHARE CRYO O_2 WITH EPS — MIN. COST & WEIGHT
- •WATER STORAGE FOR NO EXP. CONTAMINATION
- •IVA CAPABILITY FOR EMERGENCY RESCUE

TRADE STUDY RESULTS

- •USE HIGH-PRESSURE N_2 STORAGE
- •SHARE O_2 WITH EPS CRYO O_2
- •HIGH-PRESSURE GAS STORAGE FOR FF RAM PRESSURIZATION

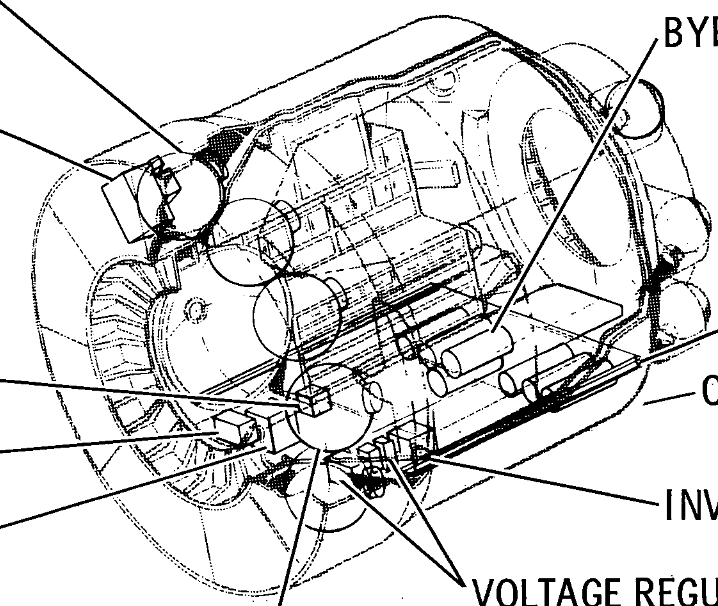
72-1810

ELECTRICAL POWER SUBSYSTEM
Ram Support Module

The figure illustrates an energy source weight comparison developed in one of the trade studies. Primary batteries were considered; however, their weight is excessive and fuel cells become strongly favored at any useful energy level. High-pressure gas reactant also shows greater weight than cryogenic reactant storage for all energy ranges. Additionally, but not shown in the curves, the high-pressure gas storage requires considerably more volume, which essentially limits its utility to short-duration, low-energy missions.

Additional trade studies compared: distribution at 28 vdc, 115 vdc, and 115 vac; and centralized and decentralized power conditioning. Selection and rationale are as shown – for all trade studies, minimum early-year and overall program cost is the prime selection criteria.

ELECTRICAL POWER SUBSYSTEM
RAM Support Module



ITEM	WEIGHT (LB.)
ELEC. CONVERSION & DISTR.	301
PRIME POWER SOURCE	1,046
ELECTRICAL WIRING	423
TOTAL (DRY)	1,770
EXPENDABLES (MAX.) (914 KWH)	904
TOTAL	2,674

72-1822

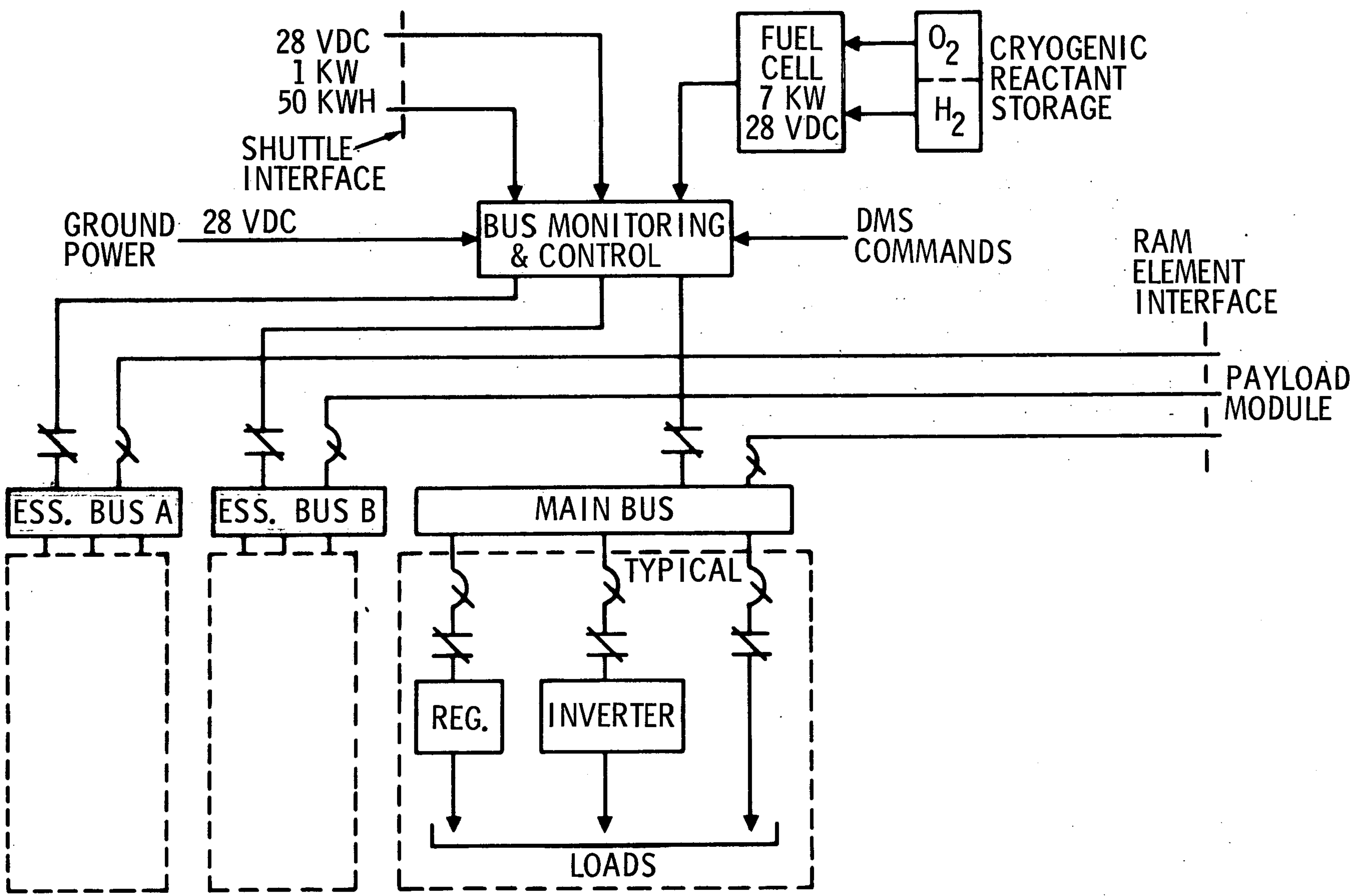
ELECTRICAL POWER SUBSYSTEM SCHEMATIC
RAM Support Module

The primary power source is a single fuel cell of the type and capacity under development for the shuttle program. The fuel cell generates 7 kw of power and cryogenic reactant storage provides a basic energy capacity of 1,034 kwh.

The monitoring and control package is internally redundant and provides fault sensing and mode selection by controlling the bus contactors. The distribution is at 28 vdc by means of three independent power channels a main bus and two essential (emergency) buses. The main bus powers all normal operations and the essential buses satisfy safety requirements. The two essential buses are powered from the shuttle. Provisions are included to interface with a payload module and maintain the safety requirements of both elements.

A generally centralized conditioning concept is used. The distribution and conditioning provide unregulated 28 vdc, ±5% regulated 28 vdc, and 115/200 vac, 400 Hz, power for subsystems.

ELECTRICAL POWER SUBSYSTEM SCHEMATIC
RAM Support Module



72-1665

ELECTRICAL POWER SUBSYSTEM
RAM Support Module

The electrical power subsystem provides electrical energy, conditioning and distribution for module subsystems and the attached experiment payloads in RAM payload modules or on pallets. Two power sources, primary and essential, are provided to meet safety requirements.

POWER GENERATION – The primary power source is a single fuel cell of the type under development for the shuttle program. Present fuel cell design is based on 7 kw average power output with a peaking capability of 10 kw for 0.1 hour. Output voltage is 24 to 32 volts; the operational life design goal is 2,000 hours. The fuel cell, reactant tanks, and supporting equipment are mounted in the external equipment bay. If the primary system fails, the orbiter provides power to operate the essential components of the EC/LS, lights, communication, and status display.

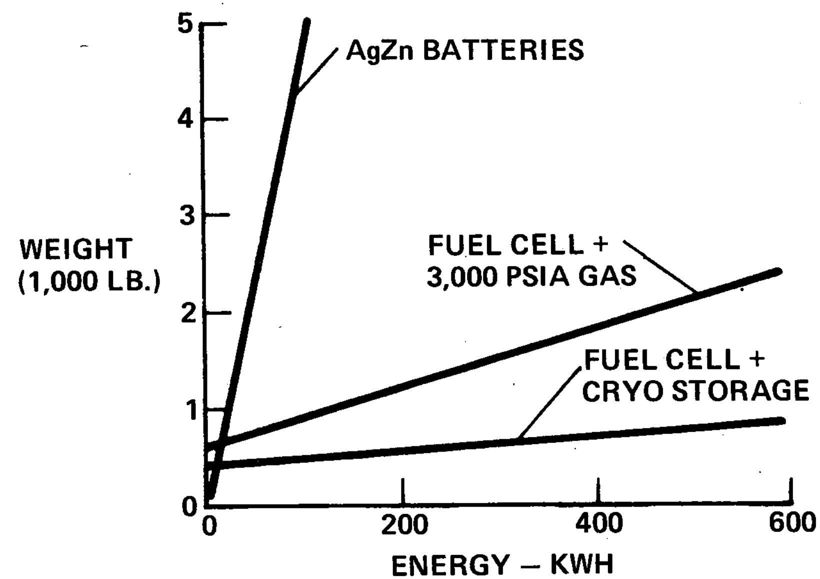
DISTRIBUTION, CONDITIONING AND CONTROL – The EPS provides three independent power channels: a main bus and two essential (emergency) buses and control. Power form the fuel cell is routed to main bus "A". Power distributed by the main bus "A" supports the ac-dc loads (including essential loads) and the experiment loads. The two essential buses are powered from the orbiter through two separate cables mated at the interface adapter assembly and which connect to wireways leading to essential bus "B" under the floor on the left side and, separately, to essential bus "C" under the floor on the right side. electrical monitoring and control package provides for fault sensing and mode selection by controlling the bus contactors. Provisions are included to interface with an attached RAM payload module and maintain the safety requirements for all elements. Other major components are located under the floor, on and behind the secondary control panel, on the control console and internally throughout the module.

LIGHTING – General area illumination is provided with fluorescent lights. Spot or high intensity lighting is via incandescent lights. Emergency lighting uses independent circuits with independent fixtures. Work area lighting is arranged so that lights may be dimmed to conserve energy.

ELECTRICAL POWER SUBSYSTEM
RAM Support Module

BASIC SUBSYSTEM PARAMETERS

• POWER	7 KW CONTINUOUS
• ENERGY	1,034 KWH (MAX.)
• DISTR. VOLTAGE	28 VDC



FUEL CELL – CRYOGENIC STORAGE SELECTION

RATIONALE FOR SELECTION

• FUEL CELL & CRYO REACTANT STORAGE	LOWEST WEIGHT & COST COMMONALITY WITH SHUTTLE
• DISTR. VOLTAGE	MINIMUM DEVELOPMENT COMMONALITY WITH SHUTTLE

IMPORTANT TRADE STUDY RESULTS

- FUEL CELL PRIMARY POWER SOURCE
- CRYOGENIC REACTANT STORAGE
- 28-VDC DISTRIBUTION - REDUNDANT BUSES
- CENTRALIZED POWER CONDITIONING

72-1666

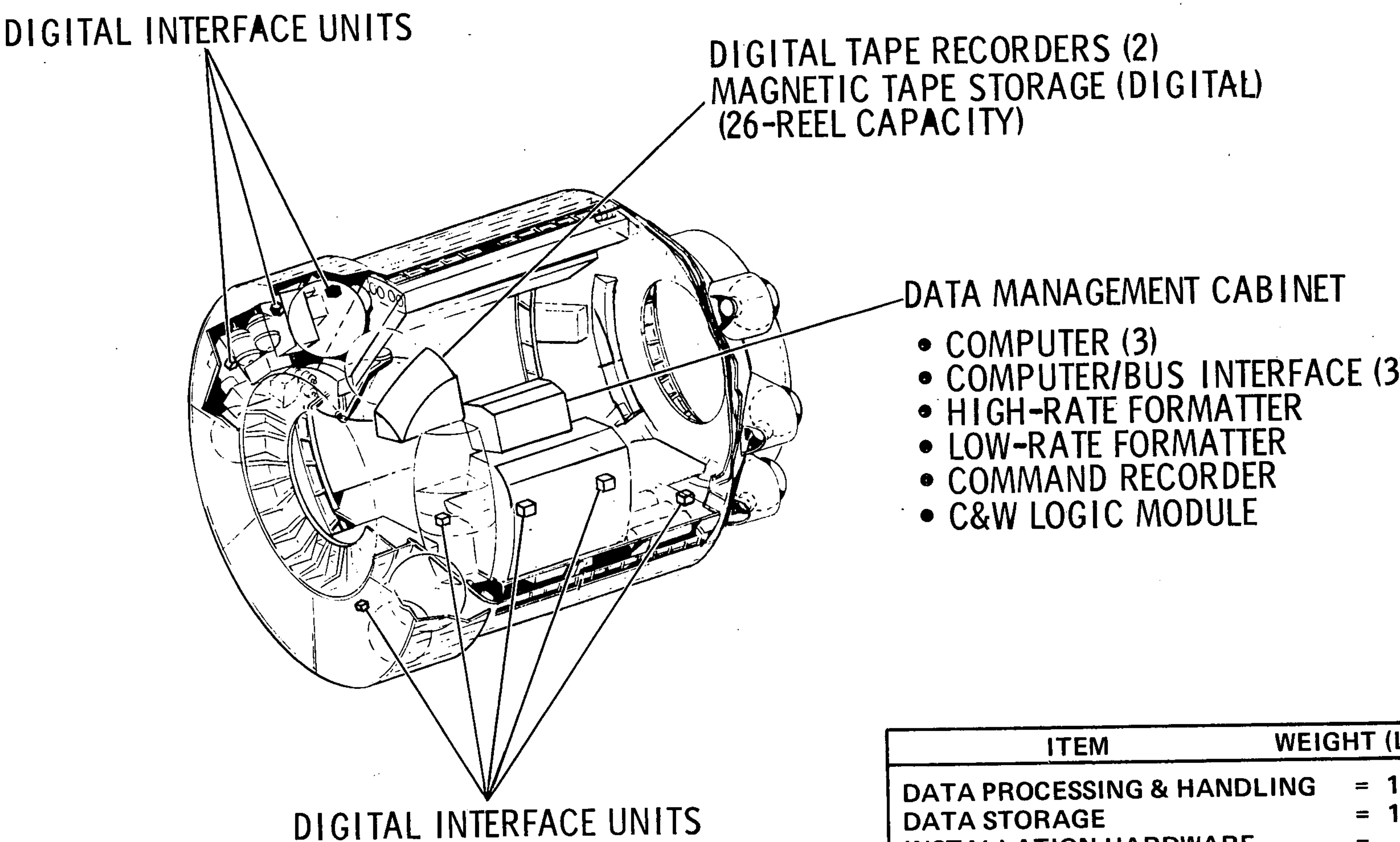
INFORMATION MANAGEMENT SUBSYSTEM
RAM Support Module

The primary components of the communication and data management system are in an enclosure directly above the integrated control and display console. Two digital tape recorders and stowage provisions for up to 26 tapes are located just forward of the main enclosure and in the conical section. Access to the tape recorders is possible without disturbance to the other crew members at the console.

Digital interface units are located on the interior and exterior of the sortie RAM to relay the pertinent data being monitored.

The prime data handling method is to store data onboard on permanent magnetic tape. Capacity is up to 8×10^9 bits – peak recording rates are up to 220 MBPS. Data processing is via a central computer.

INFORMATION MANAGEMENT SUBSYSTEM
RAM Support Module



ITEM		WEIGHT (LB.)
DATA PROCESSING & HANDLING	=	155
DATA STORAGE	=	136
INSTALLATION HARDWARE	=	29
TOTAL		320

72-1823

COMMUNICATION/DATA MANAGEMENT SUBSYSTEM SCHEMATIC
RAM Support Module

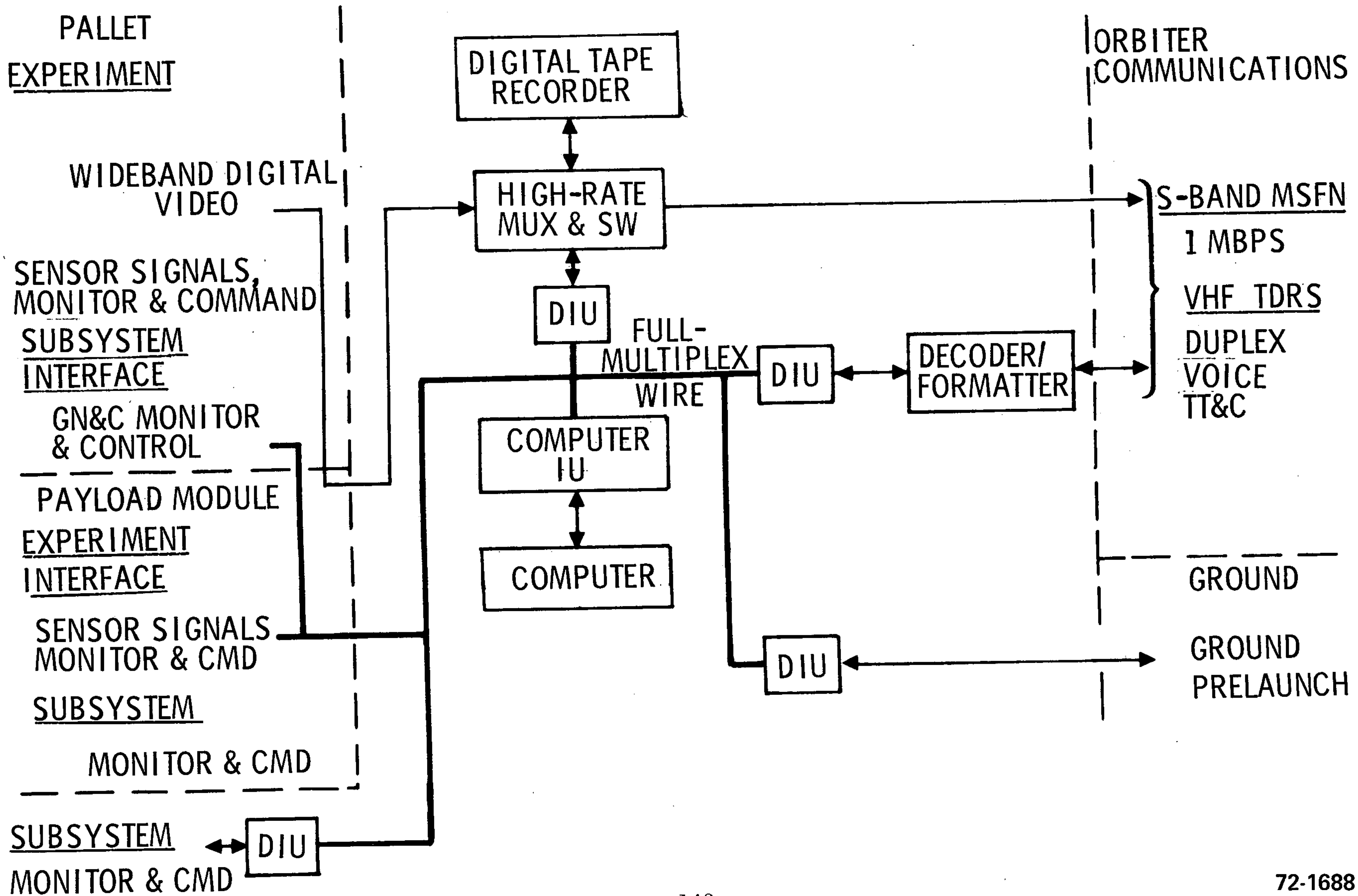
The orbiter provides all communication support for Sortie RAM by sharing its VHF/TDRS links (voice, low-rate telemetry, and command) and S-band link to the ground network (1 MBPS digital data transmission).

The basic data handling approach is to store essentially all data onboard on permanent magnetic tape. Data is recorded with volumes up to 2.3×10^{12} bits per mission and at rates as high as 50 MBPS.

A full multiplex (two-way data on a single cable) data acquisition and command distribution system is used to transfer signals between subsystems, payload module, orbiter, and ground prelaunch equipment.

Control, monitor, and automatic checkout of all subsystems and experiments are by a centralized computer configuration. Floating-point hardware is used and three computers provide safety redundancy.

COMMUNICATION/DATA MANAGEMENT SUBSYSTEM SCHEMATIC
RAM Support Module



72-1688

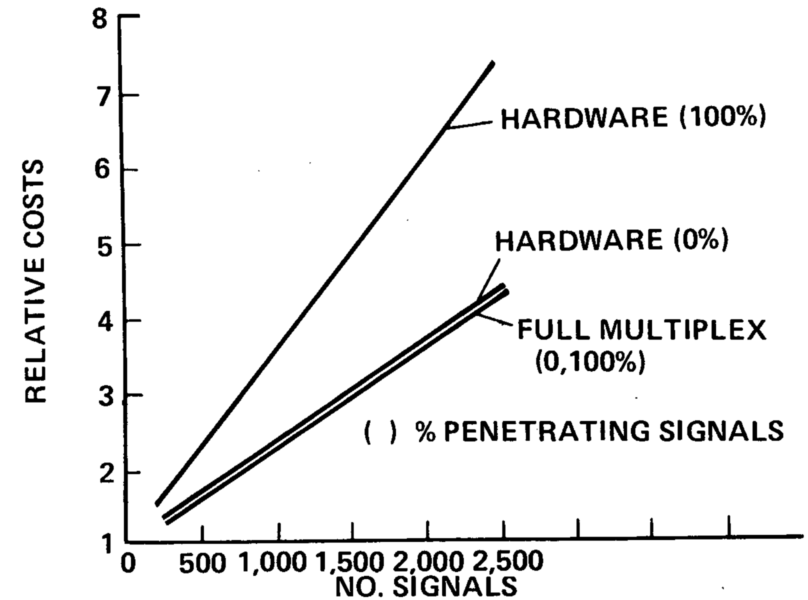
The cost comparison of a full multiplex data acquisition and command distribution system and a hardware system is illustrated. The most significant factor driving costs is the number of penetrating wires (signal sources external to the pressurized area). In the case of the hardwire approach, each penetrating signal requires two wires (one external and one internal) that essentially doubles test and integration costs relative to nonpenetrating wires. Additionally, the hardwire approach is significantly heavier, more susceptible to EMI, and lacks flexibility relative to the full multiplex system.

Additional trade studies included: centralized versus dedicated computer configurations, digital onboard magnetic tape storage versus RF transmission, and modular versus monolithic software organization. The software trade study selected the modular software structure with modularity to the separable task level because it achieves the lowest total cost for RAM software. Selection and rationale for other trade studies are as shown.

COMMUNICATIONS/DATA MANAGEMENT SUBSYSTEM
RAM Support Module

BASIC SUBSYSTEM PARAMETERS

- SIGNAL INTERFACE CAPACITY — 1,000
- COMPUTER — FLOATING POINT HDW.
- PERMANENT TAPE STORAGE — 2,300 GB/MISSION (MAX.)
- ORBITER TRANSMISSION — VOICE/DATA



DIGITAL INTERFACE COST COMPARISON

RATIONALE FOR SELECTION

- FULL MULTIPLEX SYSTEM — LOWEST COST, REDUCED EMI, ADAPTABILITY, FLEXIBILITY
- CENTRALIZED COMPUTER — LOWEST PROGRAM COSTS
- DIGITAL MAGNETIC TAPE — LOWEST COST, WEIGHT & POWER
- ORBITER TRANSMISSION — ORBITER AVAILABLE

IMPORTANT TRADE STUDY RESULTS

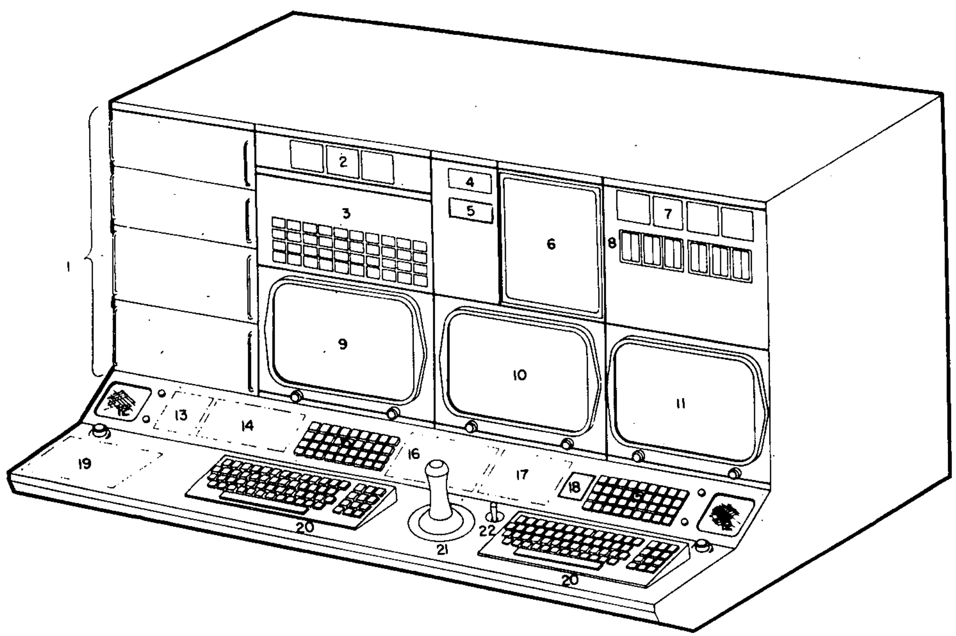
- FULL MULTIPLEX SYSTEM FOR DATA ACQUISITION & CMD DISTRIBUTION
- CENTRALIZED COMPUTER CONCEPT
- MODULAR SOFTWARE STRUCTURE
- DIGITAL MAGNETIC TAPE STORAGE

72-1705

Centralized management of major RAM C&D experiment and subsystem functions is provided by the data and subsystem console. The console provides an optimum mix of conventional, dedicated C&D, and integrated, software-oriented, multipurpose C&D. The console is sized for two-man operation. The data management computer provides the console with information through its interface with the subsystems and the experiment payload. Digital interface units provide the interface to the data management computer via the multiplex system allowing payload and subsystem C&D to be handled by software.

Caution and warning panels located on the data and subsystem console display C&W situation information. The master alarm and C&W indicators are activated when any emergency, caution, or warning situation is detected. Manual intervention is necessary to reset C&W indicators following corrective action.

CONTROLS & DISPLAYS
RAM Support Module



1. DEDICATED EXPERIMENT CHASSIS
2. ADVISORY EXPERIMENT
3. CAUTION & WARNING
4. MISSION TIME
5. EVENT TIME
6. MICROFILM VIEWER
7. ADVISORY SUBSYSTEMS
8. DEDICATED SUBSYSTEMS C&D
9. CRT EXPERIMENT PRIM
10. CRT EXPERIMENT PRIM
11. CRT SUBSYSTEM & CCTV PRIM
12. ICOM SPEAKER
13. ICOM CONTROLS
14. LIGHTING
15. FUNCTION KEYBOARD
16. MONITOR SELECTION CONTROLS
17. CCTV COMMAND CONTROLS
18. CONSOLE EMERGENCY PWR
19. CONSOLE CIRCUIT BREAKERS & PWR DIST.
20. ALPHANUMERIC KEYBOARD
21. 3-AXIS CONTROLLER
22. 2-AXIS CONTROLLER

72-1668

ONBOARD CHECKOUT SUBSYSTEM
RAM Support Module

A number of important trade studies were conducted to establish the optimum operational configuration and implementation of the onboard checkout function: identification of the optimum level of checkout, automatic versus manual operation, centralized versus decentralized checkout, and utility of BITE. Selection and rationale are as shown.

The figure illustrates the results of the level of checkout trade study. The curves show that system cost penalties incurred without checkout capability are much larger than the cost of including such capability at the subsystem and assembly level, but less than the cost of the checkout capability at the component level.

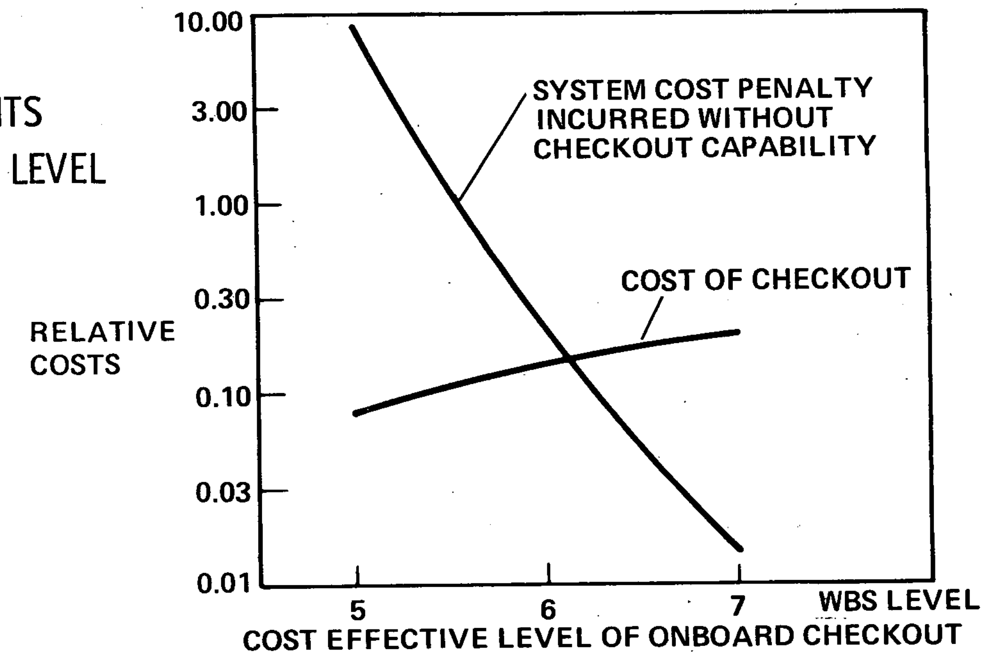
The OCS performs highly organized, repetitive functions such as status monitoring automatically, while permitting crew participation in those functions performed periodically or on an on-demand basis, such as fault isolation, redundancy switching, and checkout.

The OCS uses the CDMS data processor, data distribution system, and interfacing units. It supplies a stimuli generator and C&W logic module. The C&W function is performed concurrently with, but independent of, other checkout functions.

ONBOARD CHECKOUT SYSTEM
RAM Support Module

BASIC SUBSYSTEM PARAMETERS

- MONITORING — 650 TEST POINTS
- CHECKOUT & FAULT ISOLATION — TO ASSEMBLY LEVEL
- C&W MONITOR — 35 SIGNALS



RATIONALE FOR SELECTION

- ASSEMBLY LEVEL C/O — LEAST PROGRAM COSTS
- AUTOMATED SUBSYSTEM MONITORING — MINIMUM CREW INTERVENTION WITH LEAST COST
- CENTRALIZED SIG. COND. — MINIMUM WEIGHT, POWER & COST
- USE BITE WHERE AVAILABLE — MINIMUM C/O COMPLEXITY & LOWEST COST

IMPORTANT TRADE STUDY RESULTS

- C/O & FI TO ASSEMBLY LEVEL (WBS-6)
- AUTOMATED SUBSYSTEM MONITORING — ALL OTHER OCS FUNCTIONS MANUAL
- CENTRALIZED SIGNAL CONDITIONING
- USE BITE WHERE AVAILABLE — DO NOT MODIFY EXISTING EQUIPMENT TO ADD BITE

72-1701A

HABITABILITY PROVISIONS
RAM Support Module

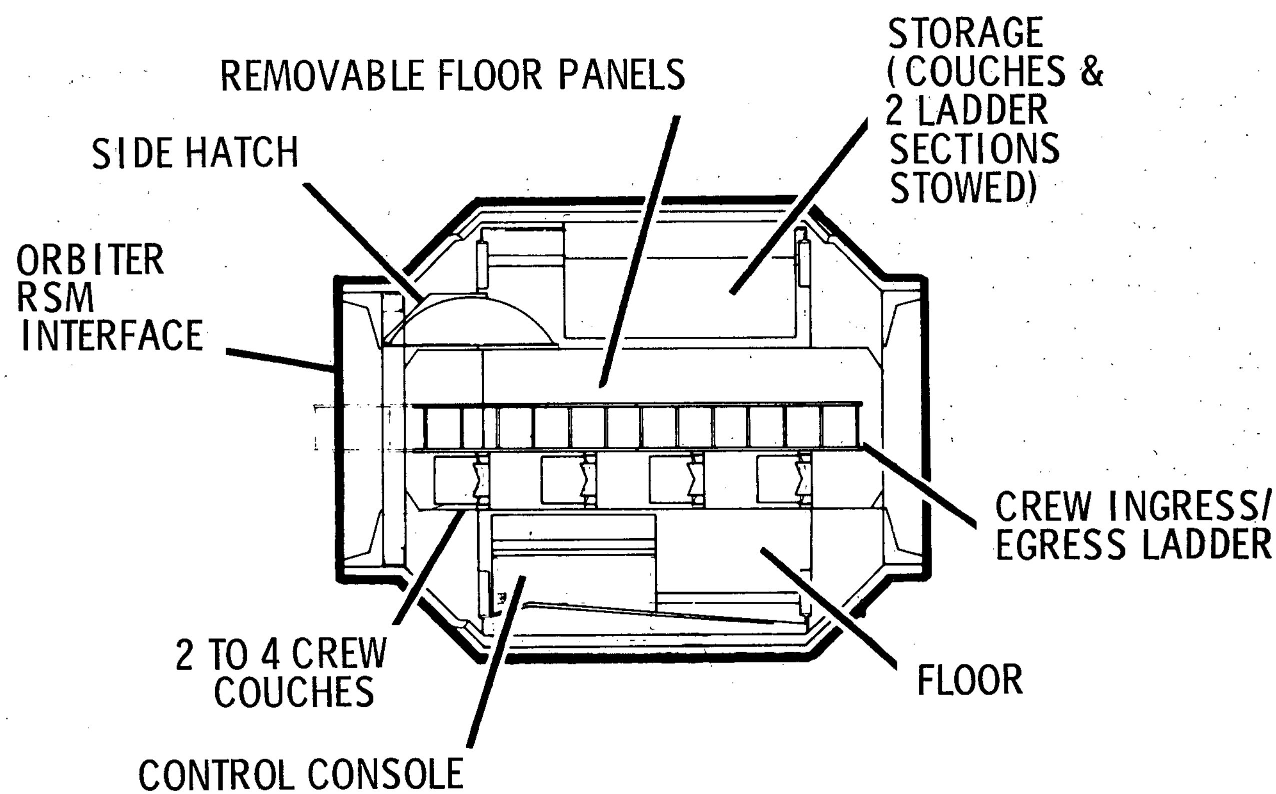
The RAM sortie module (RSM) provides the capability to expand the number of RAM payload specialists from the two used with sortie RAM to a maximum of six. The RSM contains both living and working provisions for the payload specialists, except for hygiene and food management facilities which are provided by the shuttle orbiter. The RSM provides launch/entry couches and sleeping compartments. The basic RSM configuration has two of each; the additional two of each can be installed when required. The couches are stowed during orbital operations. A ladder is provided for crew ingress and emergency egress on the launch pad. It is stored during orbital and entry flight phases.

An in-line arrangement of counches was selected based upon the results of a trade study in which simulated emergency egress confirmations were evaluated. The ladder is located adjacent to the seat brackets approximately at a crewman's shoulder position. The ladder orientation is with the rungs parallel to the RSM floor.

Two RAM crewmen continue to be accommodated by the shuttle orbiter for launch/entry seating and sleeping. All RAM crewmen use the orbiter galley and hygiene provisions.

HABITABILITY PROVISIONS
RAM Support Module

PERSONAL STORAGE
2 TO 4 SLEEP COMPARTMENTS } ABOVE CEILING

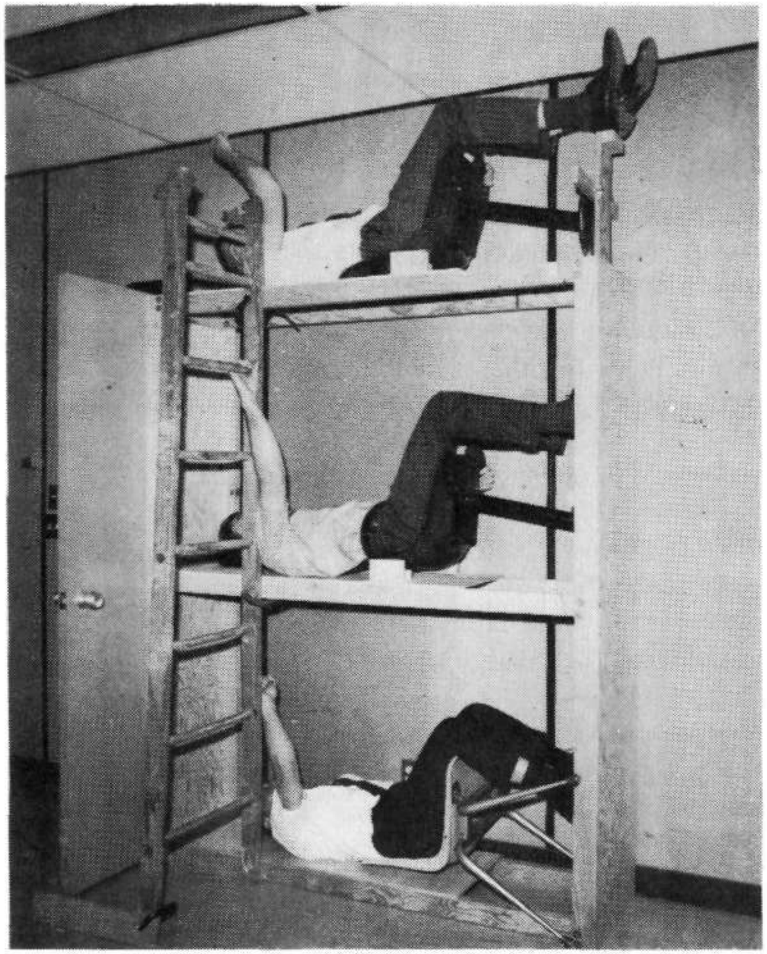


72-1799

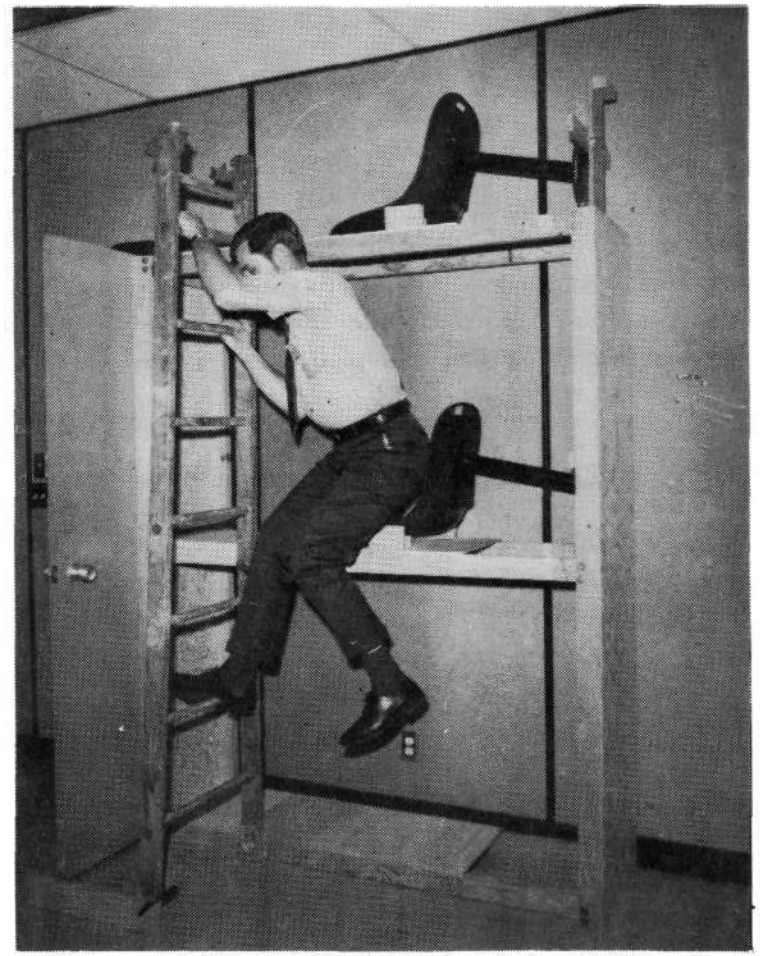
EGRESS ON THE LAUNCH PAD
Simulation – RAM Support Module (RSM)

In addressing the question of egress from the RSM for payload specialists while in their couches on the launch pad, recourse was made to the simulation setup illustrated to determine the best couch/ladder arrangements with respect to minimum exit time. Simulations were conducted with couches side-by-side and four abreast, in addition to the selected tandem configuration shown. Ladder positions other than the "right shoulder reverse" shown were also tried out. Multiple time trials were used to determine the optimum arrangement, together with 5th to 92nd percentile subjects.

EGRESS ON LAUNCH PAD
Simulation-RAM Support Module



ON-PAD ACCOMMODATION



EGRESS - FIRST MOTION

72-1726

RAM SUPPORT MODULE INTERFACES

The RAM Support Module (RSM) has several functional interfaces with the shuttle orbiter; i.e., electrical power, data, communications, caution and warning (C&W), and controls associated with C&W. Shuttle electrical power may be used during ascent/entry and serves as a backup source during orbital operations. Redundant buses are provided. RAM relies entirely upon the orbiter for communications and data transmission to earth. This is accomplished through redundant connections to the orbiter multiplex data system. A number of redundant hardwired circuits are provided for C&W signals from RAM to the orbiter crew and for associated emergency/safety control purposes.

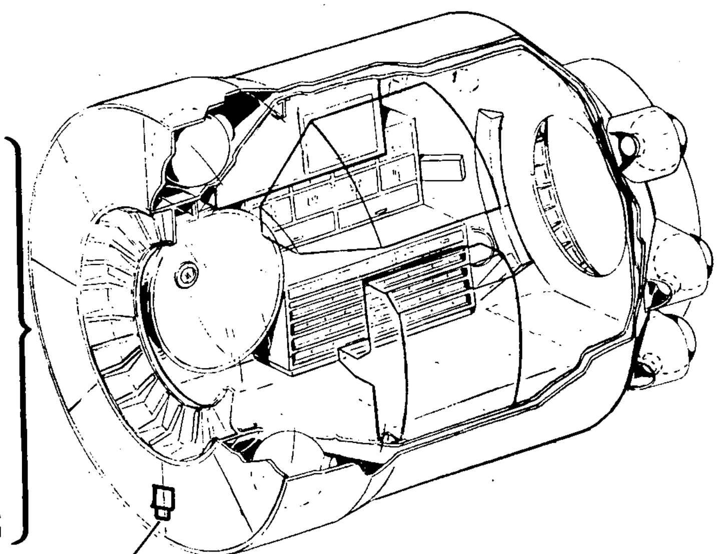
Because the RSM provides the basic resources for experiment payload operations, a relatively large number of interface functions exist between the RSM and RAM payload module. Triple-redundant buses provide electrical power to the payload module. Redundant connections to the multiplex data system transmit data to the RSM. A number of redundant hardwired circuits are provided for control signals to the payload module and caution and warning signals to the RSM. A Freon loop, external to the pressure shell, connects additional radiator area on the payload module into the RSM thermal control subsystem. A water loop provides cooling for experiment equipment and an atmospheric heat exchanger in the payload module. Atmosphere supply and return lines provide for oxygen makeup and carbon dioxide removal. Oxygen and nitrogen repressurization lines allow the payload module to be repressurized, if necessary. An air bleed-down pipe allows the module to be vented to space if required. This same line allows for airlock volumes to be scavenged when the payload module is operated in the station-attached mode. Redundant potable water supply lines are provided to service experiments, as required.

RAM SUPPORT MODULE

Interfaces

SHUTTLE INTERFACES

- 2 DC POWER BUSES, 28V, 1 KW AVG.
- 2 DATA CONNECTORS, MULTIPLEX SYSTEM
- 4 36-PIN HARDWIRE CONNECTORS, CONTROLS/ CAUTION & WARNING



GROUND SERVICING PANEL

- ELECTRICAL POWER
- COOLING LOOP
- H_2 GSE
- O_2 GSE
- GN_2 GSE
- LO_2 FILL
- LO_2 VENT
- LH_2 FILL
- LH_2 VENT

PAYLOAD MODULE INTERFACES

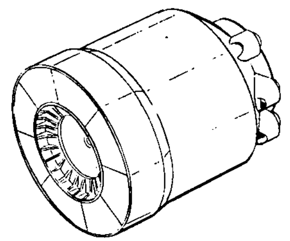
- 3 DC POWER BUSES, 28V, 4.8 KW AVG.
- 2 DATA CONNECTOR, MULTIPLEX SYSTEM
- 4 36-PIN HARDWIRE CONNECTORS, CONTROLS/ CAUTION & WARNING
- 1 FREON LOOP, RADIATOR
- 2 WATER LOOPS, COOLING
- 1 ATMOSPHERE LOOP
- 2 REPRESSURIZATION LINES O_2 & N_2
- 1 AIR BLEEDDOWN PIPE
- 2 WATER SUPPLY LINES, EXPERIMENTS

72-1694

RAM SUPPORT MODULE CAPABILITY

The pressurized RAM adaptation known as RAM Support Module (RSM) will be used to increase the number of payload specialists on-orbit over the basic orbiter capability of two. The identical structural shell of the sortie RAM is used and has the same total pressurized volume. Only nominal stroage space is, however, available to the user since subsystems and habitability provisions use most of the volume. The RSM operates in conjunction with a RAM payload module at all times, and heat rejection capability for a given payload must be determined on the combined configuration basis; the RSM alone accounts approximately for the systems installed within it. The 28-vdc, 7-kw fuel cell system provides up to 4.1 kw to the payload module interface. Integral reactant tankage for up to 1,030 kwh is provided. Data storage is handled by the use of magnetic tape. All communications are handled through the shuttle orbiter systems.

RAM SUPPORT MODULE CAPABILITY



SUBSYSTEM PARAMETER	REQUIRED BY RAM	AVAILABLE TO USER	TOTAL
STRUCTURAL VOLUME ($FT.^3$)	1,950	NOM. STORAGE	1,950
HEAT REJECTION (1,000 BTU/HR.)	UP TO 21	–	21
LIFE SUPPORT (MAN-DAYS)	–	36	36
MISSION/EXPT. SPECIALISTS (EQUIV. MEN)	~0.2	3.8 TO 5.8	4 TO 6
ELECTRICAL ENERGY (KWH)	370 TO 440	590 (MIN.)	1,030
ELECTRICAL POWER (AVG. KW)	2.3 TO 2.9	UP TO 4.1	7
DATA STORAGE (10^9 BITS)	–	1,300	1,300
DATA TRANS (10^6 B/SEC.)	–	1.0*	1.0*
DATA PROCESSING			
-MEMORY WORDS	20,000	8,000	28,000
-TIME (mSEC./SEC.)	610	390	1,000

* VIA ORBITER

72-1754

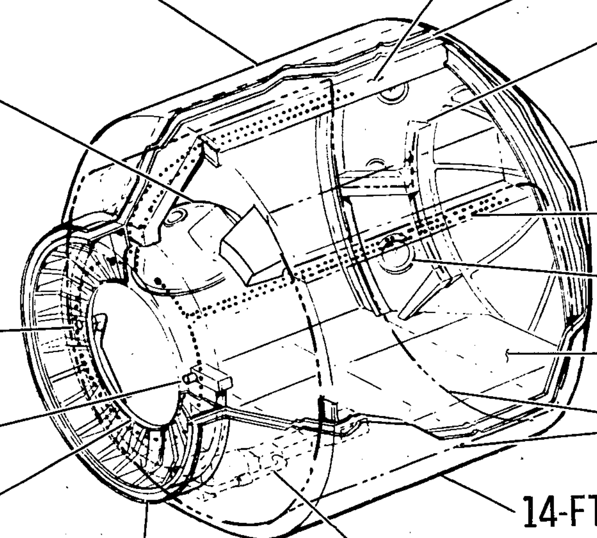
SORTIE PAYLOAD MODULE
General Arrangement

Sortie payload modules always interface with the RSM, which in turn interfaces with the shuttle. Minimum subsystems are installed in the payload module as it derives resources support from the RSM. The interior arrangement provides for easy installation and removal of experiment equipment peculiar to each payload. The 18-foot module shown is configured to use the same primary structural assemblies as the sortie RAM. The 32-foot payload module (not shown) is structurally identical except sidewall length is 24 feet instead of 10 feet. A pallet is attached to the 18-foot module for specific missions.

Atmospheric conditioning essential components are installed below the floor with ducting routed forward, around the interface assembly, up and along the upper internal surface. The installation is the same as for the sortie RAM, but with the omission of provisions for LiOH canisters and the water separator. An electrical distribution center is located forward on the left side, in the conical transition area. This center contains power, control, and data circuits. The internal TCS components consist of a water loop brought through the interface with the RSM for experiment cold plating and then returned to the RSM through the interface.

Cabinets for two IVA emergency suits and two umbilical cords are located on each side of the vehicle in the forward transition cone area. Just above each are the IVA control station with face masks. The umbilicals plug in at these stations. The left IVA control station and right suit/umbilical storage are similar to the sortie RAM installation. A cabinet enclosure for housekeeping equipment is located on the forward right side in the conical transition area, above the IVA control station. Virtually all internal volume above the floor is available for experiment apparatus installation. A removable 102-inch diameter aft domed bulkhead can be replaced by special bulkheads capable of supporting internal viewing instruments and large external sensors.

SORTIE PAYLOAD MODULE
General Arrangement



ITEM	WEIGHT (LB.)	
	L = 18 FT.	L = 32 FT.
STRUCTURE	4,934	7,795
SUBSYSTEMS	864	949
TOTAL	5,798	8,744

18-FT. OVERALL LENGTH (SHOWN)
32-FT. OVERALL LENGTH (ALTERNATIVE)

72-1691

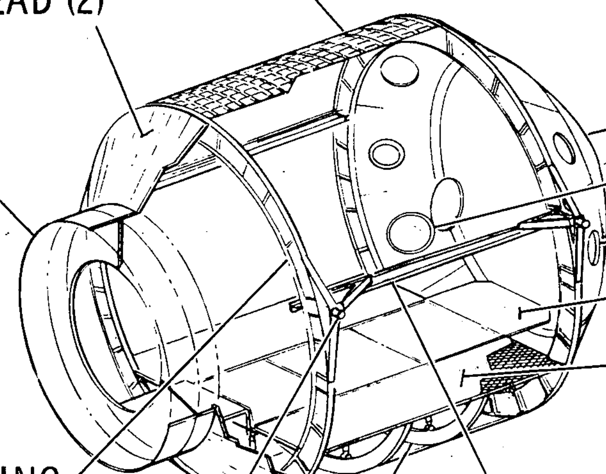
SORTIE PAYLOAD MODULE STRUCTURE

The RAM payload module structure provides support for experiments and containment of a livable atmosphere so that experiments may be performed and equipment maintained in a shirtsleeve environment. The structure must hold internal pressure and react external forces due to boost and maneuvering loads imposed by the orbiter and by docking procedures.

The structure is made up of the pressure shell, which consists of cylindrical walls, bulkhead, closures, and mating adapter. It also consists of the environmental protection system and secondary structure that includes internal floors, and internal and external equipment supports.

The structure is basically a cylindrical shell with conical bulkheads. It has a maximum internal diameter of 160 inches and a diameter over the cylindrical section of 14 feet. Overall length of the structure is approximately 18 feet and 32 feet, in the two available versions.

SORTIE PAYLOAD MODULE STRUCTURE



MATERIAL NOTES

WELDED PRESSURE SHELL	2219-T851 Al
SECONDARY STRUCTURE	2024-T3 Al
RAM ORBITER FITTINGS	4340 STEEL

ITEM	WEIGHT (LB)
PRESSURE SHELL	755
BULKHEADS	1,197
REINFORCING ATTACH. MEMBERS	969
ORBITER ATTACH. & BACKUP	673
FLOORS	361
BASIC WT.	3,955
RADIATOR/METEOROID PROTECTION & INSULATION (NOT SHOWN)	1,531
TOTAL	5,486

72-1671A

The structure of the sortie payload module consists of a 160-inch diameter cylinder either 288 or 120 inches long sandwiched between two 45-degree conical bulkheads. A spherical closure bulkhead is bolted to the aft conical bulkhead. The MDAC docking adapter is bolted directly to the conical bulkhead on the sortie payload modules. The floor structure extends over the forward 120 inches of the cylindrical section and is identical to the sortie RAM floor. The utility tunnels also will be identical to those used on sortie RAMs.

The MDAC docking adapter, the two 45-degree conical bulkheads and the closure bulkhead are all identical to those used in the sortie RAM.

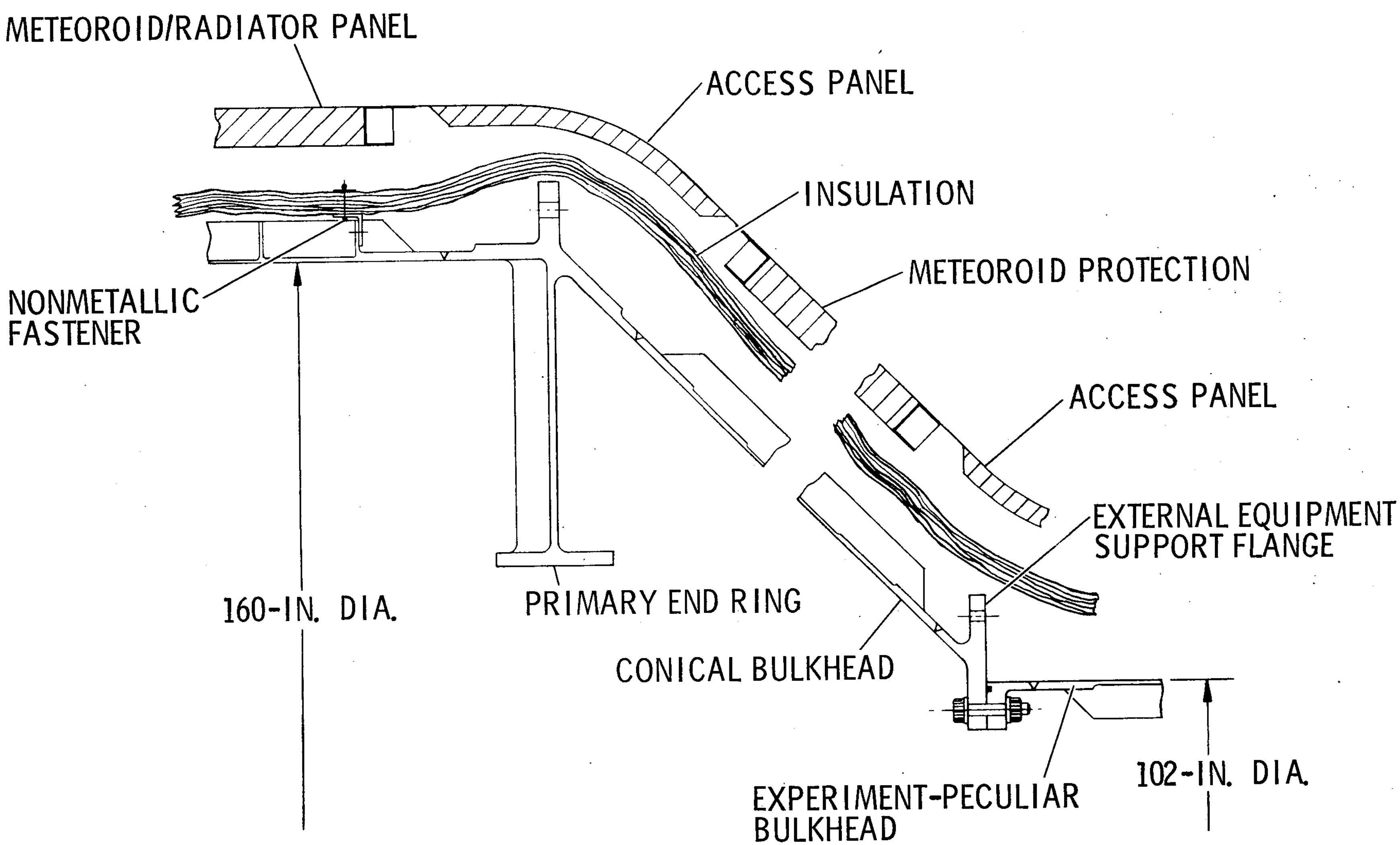
The cylindrical sidewall used on this module consists of three panels either 288 or 120 inches long rolled to the 160-inch inside diameter. It has two primary end rings identical to those used on the sortie RAM. Two longitudinal I beams are welded into the cylindrical section at a location 15 degrees above the horizontal centerline. These two beams are identical to those on the sortie RAM except for their lengths. The cylindrical panels are made with integrally machined waffle grid stiffeners, identical to that on the sortie RAM.

The sortie payload module is never used in the orbiter without a RAM support module so it does not require the forward RAM/orbiter attachment fittings.

A similar radiator/meteoroid bumper system is used on the payload modules as on the sortie RAMs, for 18-foot sortie payload modules the installation is identical. For the 32-foot sortie payload module, the environment protection system over the cylindrical section is made from two sets of identical panels nine feet long and a set three feet long.

Environmental protection of the conical bulkhead and the closure dome uses the same sandwich construction as the cylindrical section but without the radiator tubes.

SORTIE PAYLOAD MODULE STRUCTURE
Details



72-1760A

The pressure wall thickness (0.070 inch) of the cylindrical sidewall was selected by manufacturing minimums and because it is an optimum design for the waffle structure. The dimensions of the waffle were selected by determining the maximum equivalent axial load N_x (lb./in.) for each of the fifteen RAM configurations. This load had a maximum value of approximately 600 lb./in. and was used to design the waffle structure for all RAM pressurized modules.

For commonality, all meteoroid bumpers have been standardized. The primary bumper is 0.016 inch and the secondary bumper is 0.010 inch thick. These were determined by the penetration probability requirements, the surface area of the largest pressurized module, and by the longest RAM mission.

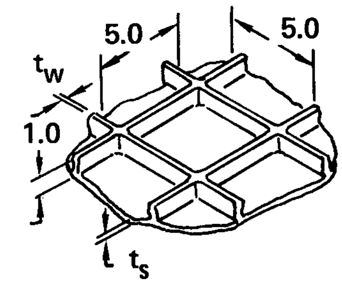
The five-point RAM/orbiter attachment fitting concept was derived from the requirement of static determinacy. One implication of this requirement is that the longitudinal loads are reacted at one location; this load results in a large couple or moment induced into the module sidewall. An internal beam structure was selected for this task as it yields the lowest weight system, is the best from manufacturing considerations, and – most important – neither cuts through the radiator system nor induces thermal shorts into the basic module structure.

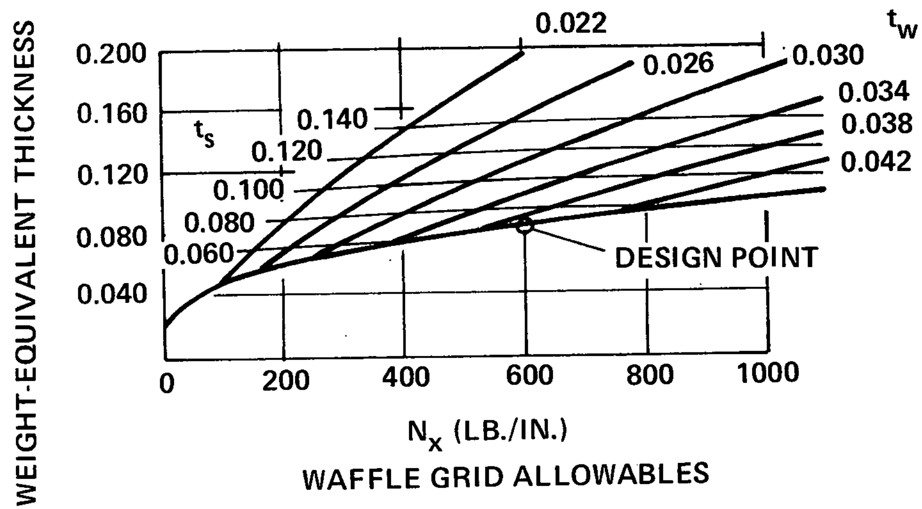
Data developed in this study shows that 2219-T851 aluminum alloy is the best material for components of the pressurized RAM module. It was selected on the basis of its excellent corrosion resistance, fracture toughness, weldability, and machinability.

STRUCTURAL SUBSYSTEM
Sortie Payload Module

BASIC SUBSYSTEM PARAMETERS

- 0.070-IN. PRESSURE SHELL THICKNESS
- 0.016-IN. METEOROID BUMPER
- 0.010-IN. SECONDARY BUMPER
- FIVE-POINT RAM/ORBITER ATTACHMENT
- INTERNAL BEAMS FOR ORBITER ATTACH FITTINGS
- 2219 ALUMINUM ALLOY





WAFFLE GRID ALLOWABLES

RATIONALE FOR SELECTION

- MANUFACTURING MINIMUMS
- P_0 = 0.995 FOR 1.0 YEAR
- PROTECTION OF INSULATION
- BY STATIC DETERMINACY
- TO REDUCE HEAT SHORTS & NOT REDUCE RADIATOR AREA
- WELDABILITY, FRACTURE TOUGHNESS & CORROSION RESISTANCE

SIGNIFICANT STUDY RESULTS

- SIDEWALL STIFFENING REQUIREMENTS MINIMAL WITH 0.070-IN. SKIN THICKNESS
- WAFFLE GRID SIDEWALL - LIGHTEST
- LONG LIFE CONSIDERATIONS - NOT CRITICAL
- MAXIMUM N_X = 533 LB./IN. (L8S2B)

72-1795

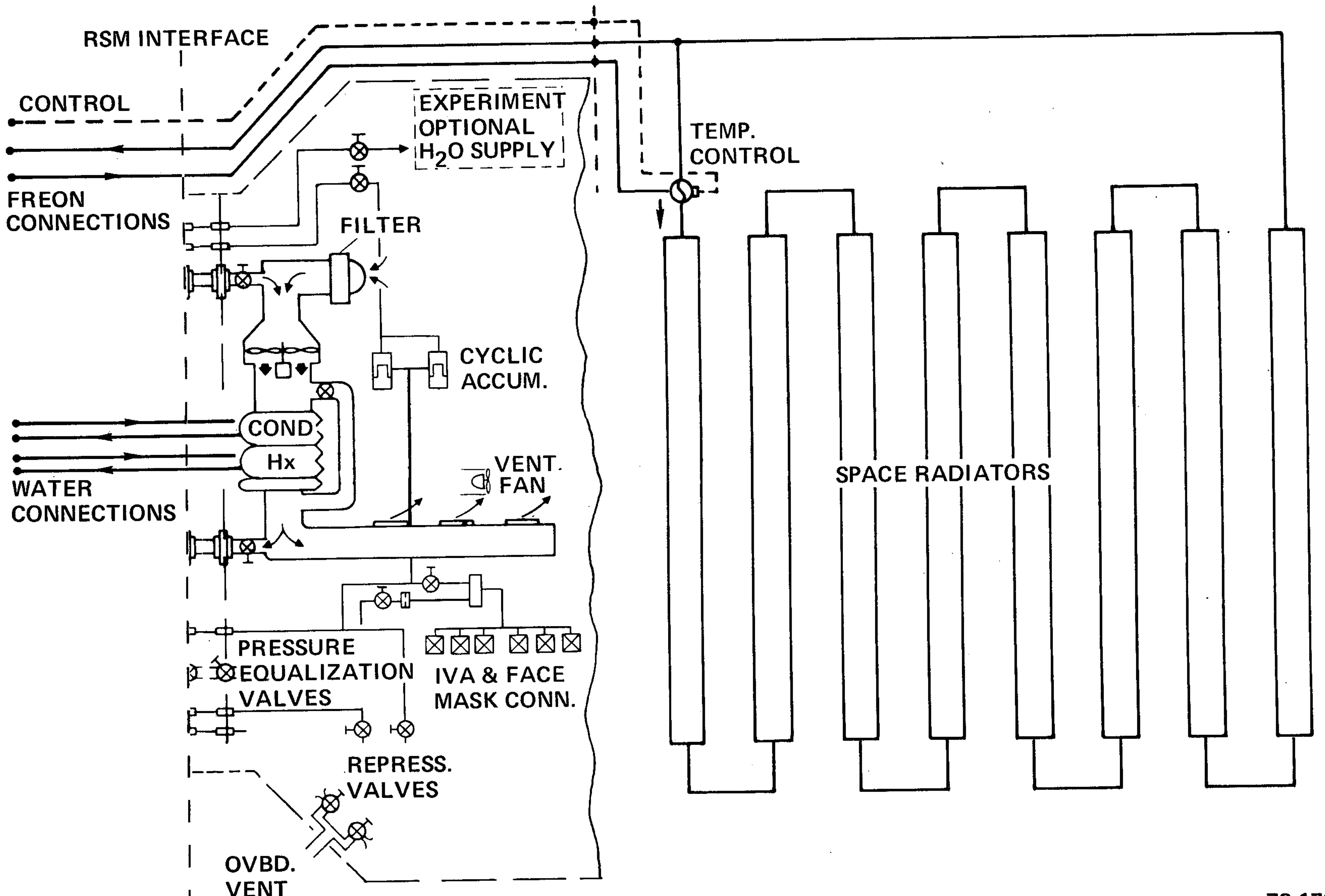
ECLS/TCS SCHEMATIC
Sortie Payload Module

Both the environmental control and thermal control subsystems (ECS and TCS) interface with the RAM support module (RSM). All TCS pumping systems are in the RSM. Freon is supplied to the payload module radiators to obtain additional heat rejection capability.

The RSM water loop extends into the habitable portion of the payload module and passes through a condensing heat exchanger to transfer heat from all internal sources back to the intercooler in the RSM. The ECS provides compartment temperature and humidity control. Humidity condensate is transferred to storage tanks in the RSM. A portion of the air is continuously recirculated back to the RSM atmosphere revitalization system for CO_2 and odor control. There are no LiOH canisters in the air loop of the condensing heat exchanger as there are in the RSM heat exchanger. Repressurization gases are provided to the payload repressurization valves. The same gas supply also provides IVA connections for up to six payload specialists. Support is limited to the purge flow of oxygen and nitrogen to the IVA suits in the event of contingency depressurized or contaminated cabin operations. The combined gas flow rate must be maintained at a minimum of about eight pounds per hour to prevent the buildup of heat in suit under these conditions. The EC/LS subsystem can provide pure oxygen at this rate for four payload specialists and can accommodate six payload specialists with 2/3 oxygen and 1/3 nitrogen mixture for a nominal 8-psia suit pressure.

Independent cabin pressure relief, both positive and negative, is provided through the cabin pressure relief valve. Automatic relief is provided when either the pressure in the module exceeds 16.0 psia or the negative differential pressure exceeds 0.5 psi. Negative pressure relief is necessary to protect the structure from buckling.

ECLS/TCS SCHEMATIC
Sortie Payload Module



72-1782

SORTIE PAYLOAD MODULE INTERFACES

Because the RAM Support Module (RSM) provides the basic resources for experiment payload operations, a relatively large number of interface functions exist between the RSM and RAM payload module. Triple-redundant buses provide electrical power to the payload module. Redundant connections to the multiplex data system transmit data to the RSM. A number of redundant hardwired circuits are provided for control signals to the payload module and caution and warning signals to the RSM. A Freon loop, external to the pressure shell, connects additional radiator area on the payload module into the RSM thermal control subsystem. A water loop provides cooling for experiment equipment and an atmospheric heat exchanger in the payload module. Atmosphere supply and return lines provide for oxygen makeup and carbon dioxide removal. Oxygen and nitrogen repressurization lines allow the payload module to be repressurized, if necessary. An air bleed-down pipe allows the module to be vented to space if required. This same line allows for airlock volumes to be scavenged when the payload module is operated in the station-attached mode. Redundant potable water supply lines are provided to service experiments, as required.

When a RAM Pallet is attached to the payload module, all necessary resources such as power and cooling are provided from the RSM and all data goes to it. Control functions are initiated within the pressurized volume and C&W signals are displayed therein. To accomplish these functions, redundant electrical power buses, multiplex data connectors and hardwired control/C&W signal paths are provided between the payload module and pallet. A single Freon experiment cooling loop is provided.

Some experiment payloads required ground services not available via the RSM. These are provided, as necessary, through a ground servicing panel on the forward end of the payload module similar to that on the RSM and Sortie RAM. This is not reconnected when the RAM is returned to the cargo bay upon completion of orbital operations. All unused gases/liquids will be vented to space. An example is a propellant transfer experiment which requires liquid hydrogen and high pressure helium loading on the launch pad.

A number of ground servicing functions are required by RAM while on the launch pad. Some are also used following return landing before RAM is removed from the orbiter cargo bay and may also be used following other ground operations, as necessary. Electrical power is provided for use before the RSM and orbiter systems are started. A ground cooling loop to onboard GSE heat exchanger is used to absorb RAM heat until T-5 seconds. Cryogenic oxygen and hydrogen tanks and gaseous nitrogen tanks are filled on pad. They are also drained following landing. Gaseous makeup oxygen may be supplied to RSM on pad and excess gaseous hydrogen vented from the cells.

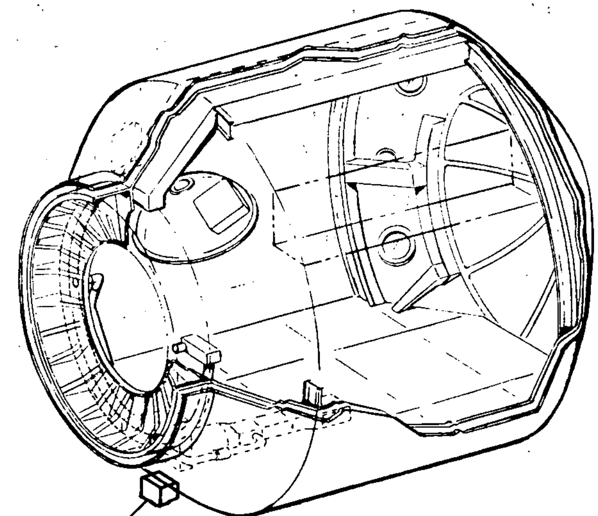
The RSM ground servicing connections are disconnected from the orbiter interface panel before RAM is deployed from the cargo bay for operations and remotely reconnected following return to the cargo bay. The ground services are provided from GSE through an umbilical arm to a payload service panel on the side of the orbiter.

SORTIE PAYLOAD MODULE

Interfaces

RSM INTERFACES

- 3 DC POWER BUSES, 28V, 4.8 KW
- 2 DATA CONNECTORS MULTIPLEX SYSTEM
- 4 36-PIN HARDWIRE CONNECTORS, CONTROLS/ CAUTION & WARNING
- 1 FREON LOOP, RADIATOR
- 2 WATER LOOPS, COOLING
- 1 ATMOSPHERE LOOP
- 2 REPRESSURIZATION LINES, O_2 & N_2
- 1 AIR BLEEDDOWN PIPE
- 2 WATER SUPPLY LINES, EXPERIMENTS



PALLET INTERFACES

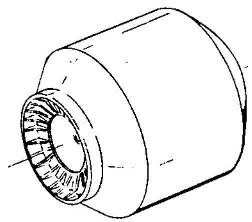
- 2 DC POWER BUSES, 28V, 4.8 KW AVG.
- 2 DATA CONNECTORS, MULTIPLEX SYSTEM
- 4 36-PIN HARDWIRE CONNECTORS, CONTROLS/C&W
- 1 FREON LOOP, COOLING

72-1696

SORTIE PAYLOAD MODULE CAPABILITY

The pressurized RAM adaptation known as RAM payload module will be used to increase the amount of pressurized volume available for the installation of experiment equipment. In the sortie mission mode, resources are provided by the RAM Support Module. The Payload Module uses the identical structural shell of the sortie RAM and RSM in its shorter (18-ft.) version, and an extended cylindrical section in its longer (32-ft.) version. Radiators on the outer shell work in conjunction with the TCS of the RSM to provide heat rejection adequate to cover fuel cell output and cooling, plus loads from peaking batteries integral to some experiment setups. Fuel cell reactants required for energy beyond that available from RSM are a concern of the experiment integrator but may be readily installed external to the RAM payload module.

SORTIE PAYLOAD MODULE CAPABILITY



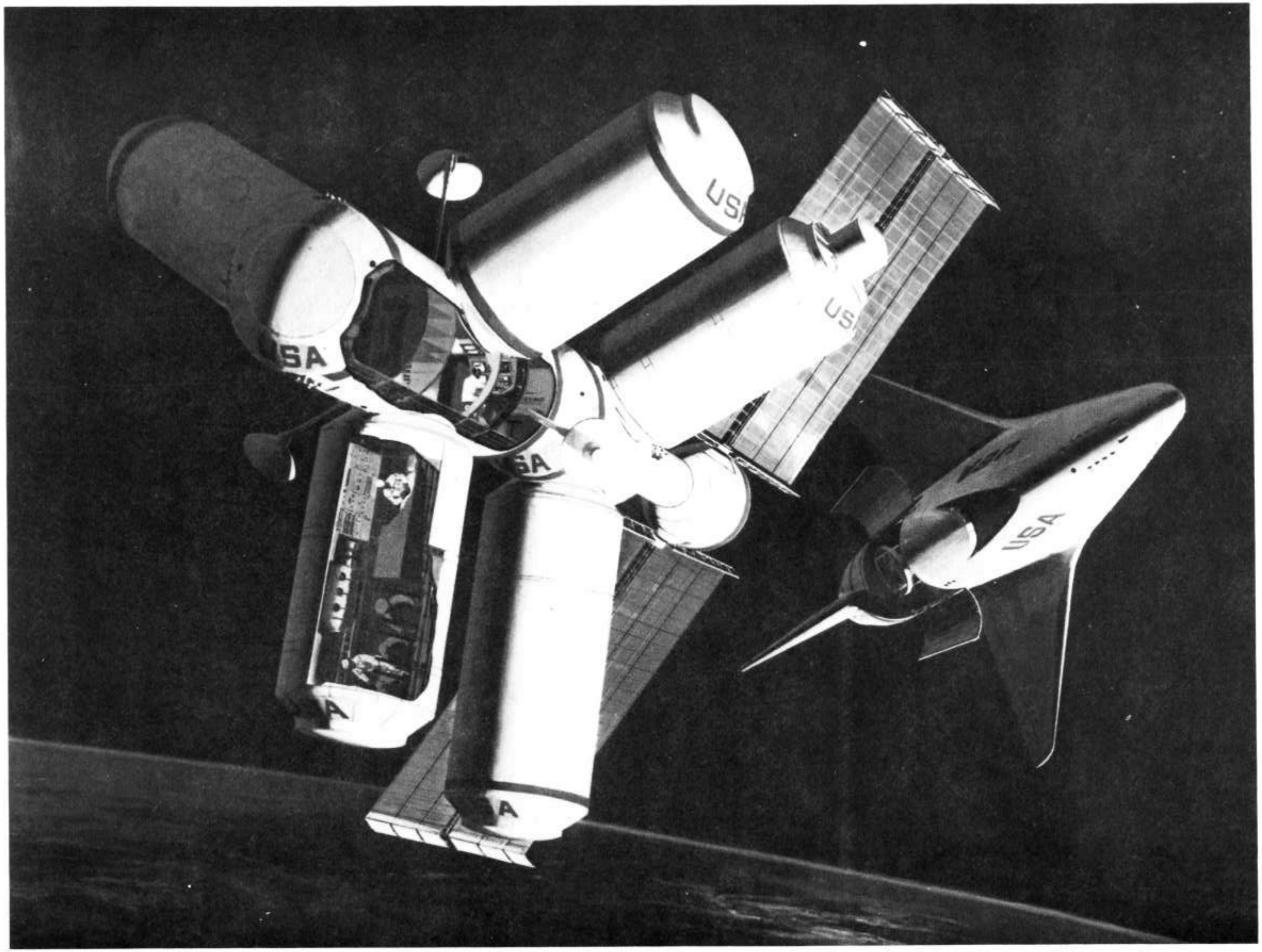
SUBSYSTEM PARAMETER	REQUIRED BY RAM	AVAILABLE TO USER		TOTAL	
		18 FT. P/M	32 FT. P/M	18 FT. P/M	32 FT. P/M
STRUCTURAL VOLUME ($FT.^3$)	533	1,377	3,327	1,910	3,860
HEAT REJECTION (1,000 BTU/HR.)	4 TO 5	UP TO 10	UP TO 25	12 TO 15	UP TO 32
ELECTRICAL ENERGY (KWH)	35 TO 70	520 (min.)	520 (min.)	590 (min.)	590 (min.)
ELECTRICAL POWER (AVG. KW)	0.3 TO 0.6	UP TO 3.5	UP TO 3.5	4.1*	4.1*

*SUPPLIED BY RSM

72-1755

SPACE STATION RAM MISSION

When the Modular Space Station becomes operational, RAM payload modules may be berthed at ports allocated for this purpose. A full range of resources will be supplied from the station interface for RAM operation with the possible exception of cooling capability. Station-attached RAM payload modules have been predesigned with an independent heat rejection system. RAMs will be delivered to the station and docked by the shuttle orbiter. After extended periods of use, RAMs may be returned to the ground for refurbishment and update.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STATION-ATTACHED PAYLOAD MODULE

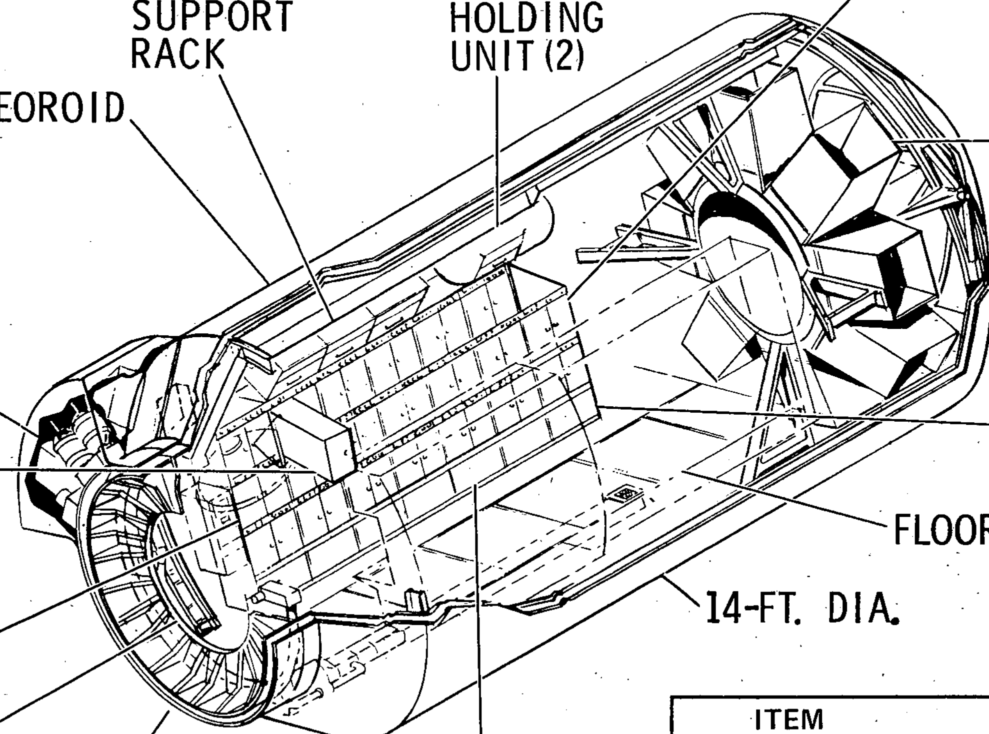
Life Sciences Payload

Station-attached missions use 18 and 32-foot length payload modules. The 32-foot module is shown for Life Sciences Payload L8A2B. Most subsystem support is derived from the Space Station. Primary differences between the station-attached and sortie payload modules are with respect to structural support within the cargo bay and added thermal systems for station-attached modules to provide their own complete heat rejection capability.

This payload incorporates biology experiments, including vertebrate, invertebrate, plants, and cells and tissues. The equipment is grouped for ease of access by the experimenter. Storage for life science components and experiment equipment is provided. Preparation and storage of biology samples for return to earth or further study is also provided. A centrifuge for providing artificial gravity for biology experiments is installed in the aft end of the payload module.

The RAM EC/LS system is installed below the floor with distribution ducts in the overhead. The cage module EC/LS system is independent of the normal system, supplied by the experiment equipment, installed in back of the cage modules.

STATION-ATTACHED PAYLOAD MODULE
Life Sciences Payload



PAYLOAD L8A2B SHOWN: 32-FT. OVERALL LENGTH

ITEM	WEIGHT (LB.)	
	L = 18 FT.	L = 32 FT.
STRUCTURE	5,970	8,072
SUBSYSTEMS	2,370	2,372
EXPERIMENTS	4,932	14.232
CREW EQUIP.	124	124
RESIDUALS	800	800
	14,196	25,600

72-1692

EXPERIMENT ACCOMMODATION PROVISIONS

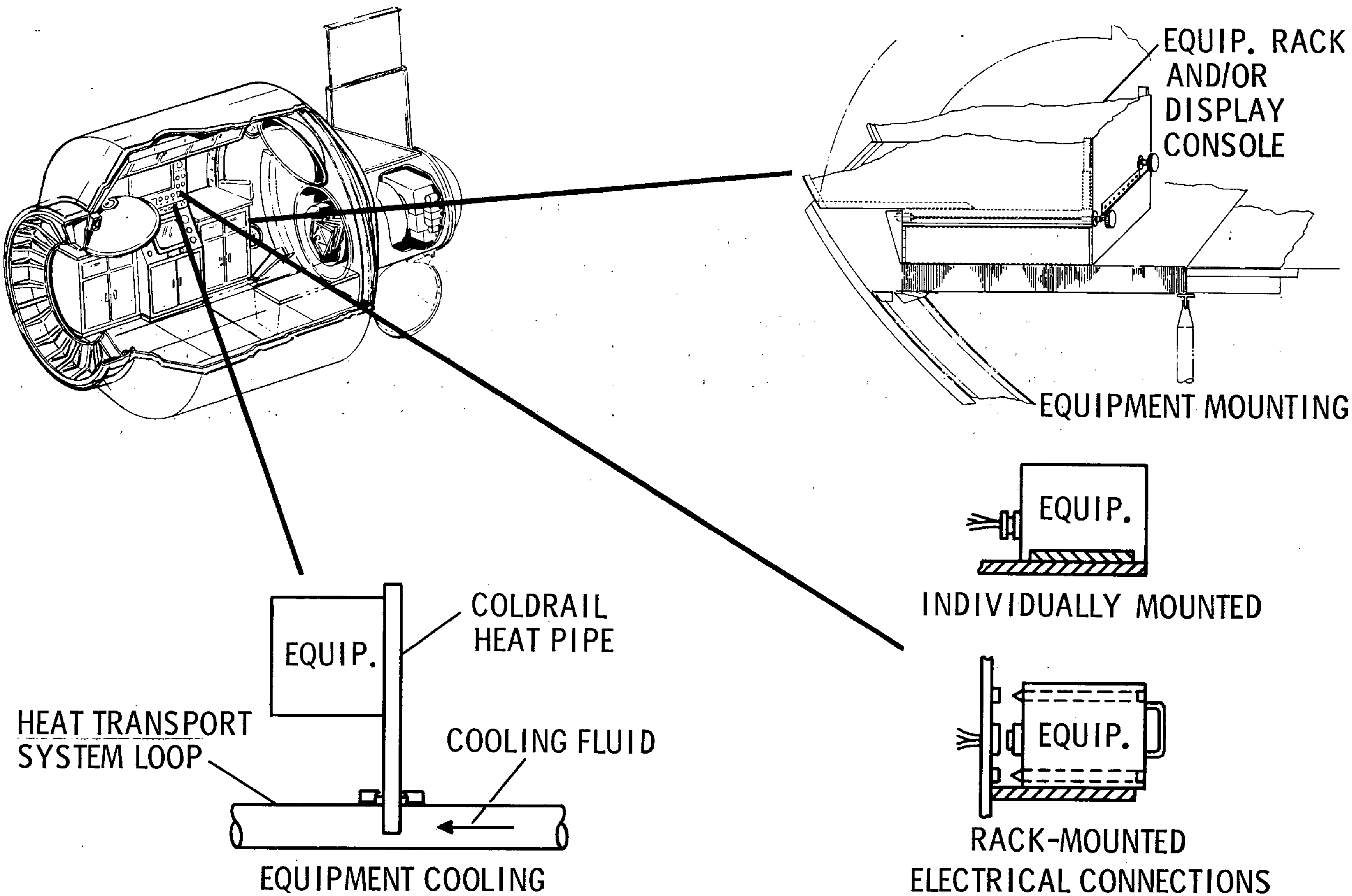
A prime objective of the RAM preliminary design has been to define a vehicle structure/subsystems resources/internal arrangement which, together with certain payload-integration equipment, will provide the required flexibility to support a wide range of payloads and satisfy the experiment user requirements.

The approach to the internal mounting of experiment equipment in the sortie RAM or payload module is by means of racks attached to the floor or panels attached to the overhead structure. The consoles and/or equipment racks are mounted on four-inch-high channel supports. These channel supports are installed longitudinally on the RAM outboard floor. They are attached by bolts into threaded inserts in the floor. Inserts are installed in the floor for the different length channels required for various payloads. This permits rapid removal and replacement of console support channels for refurbishment or maintenance purposes.

The consoles and/or equipment racks are mounted on hinges to the console support channels. With the console hinged inboard, the harnesses, flexible tubing, or other utilities may be disconnected. Harnesses and/or flexible tubing are routed from the outboard trough in the floor to the inboard side of each console as near to the hinge line as possible.

An active thermal heat sink for the equipment in the consoles and racks will be integrated into the thermal control subsystem. The internal experiment equipment thermal load is equally divided between the water loop cooling and the air-cooled system.

EXPERIMENT ACCOMMODATION PROVISIONS
Sortie RAM



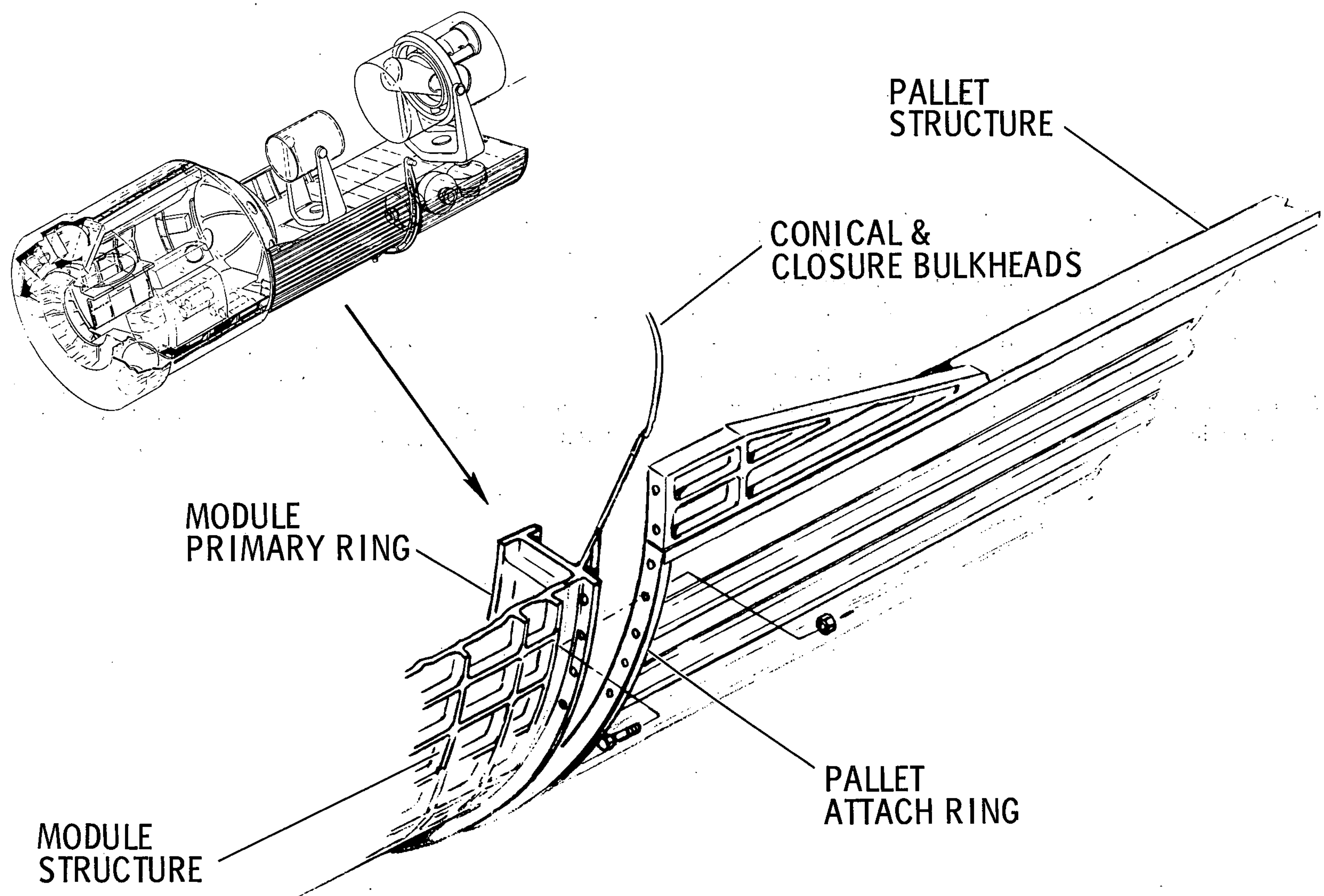
72-1704

SORTIE RAM/PALLET ATTACHMENT

The pallet structure is essentially a half-cylinder made from sheet metal 80 inches in radius. The forward end of the pallet has a bolt ring flange that mates with a similar flange on the sortie RAM aft primary ring. The two major longerons on the upper edge of the pallet and the floor beam longerons all end at the bolt flange. The longerons and the two machined fittings bolted to the upper longerons serve to spread the load uniformly into the bolt ring flange.

The pallet is attached to the sortie RAM with high-strength bolts. The bolted joint and the forward 12 inches of the pallet are covered by Superfloc insulation and a protective shield. This shield attaches to the pallet structure and at its forward end to the meteoroid/radiator bumper on the module. The area not covered by the pallet is protected by the standard meteoroid bumpers that cover the aft conical bulkhead and by the primary end ring access panels.

SORTIE RAM/PALLET ATTACHMENT



72-1784

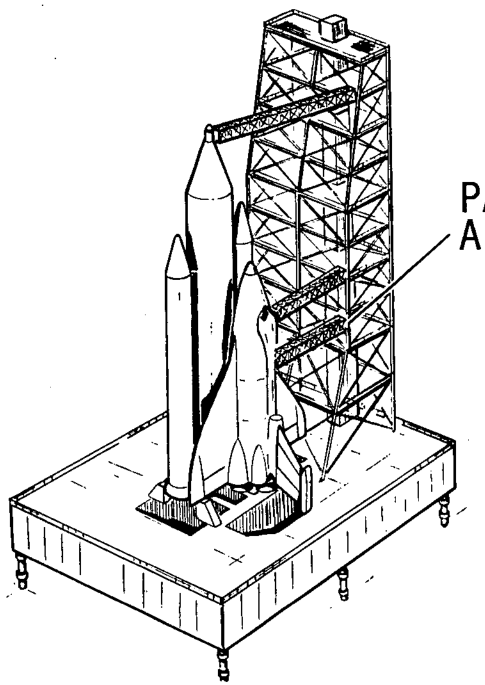
GROUND SUPPORT EQUIPMENT

No special support equipment is required for RAM support at the launch pad, except for a payload swing arm that extends from the service tower to the orbiter vehicle payload service panel. RAM support service lines will be routed through the payload swing arm to provide umbilicals for the connections specified on the chart. At T-5 seconds, all umbilicals are disconnected. It will be necessary to provide automatic reconnect capability to ensure thermal control capability in event of a launch hold after T-5.

Support equipment is also used in the maintenance, servicing, and refurbishment area. Listed in the chart are four classes of major support equipment required for RAM project: handling and transport, checkout and control, servicing, and auxiliary equipment consisting of support equipment that does not fall into the other three categories.

GROUND SUPPORT EQUIPMENT

LAUNCH PAD SUPPORT



CONNECTIONS:

- MONITOR & CONTROL LINES
- ELECTRICAL POWER
- CRYOGEN FILL & VENT LINES
- PRESSURIZED GAS LINE
- TCS COOLANT LINE

MAJOR SUPPORT EQUIPMENT

HANDLING & TRANSPORT

CHECKOUT & CONTROL

SERVICING

- ELECTRICAL POWER
- EXPENDABLE REPLENISHMENT
- GROUND COOLING
- CONDITIONED AIR

AUXILIARY

- PROTECTIVE COVERS
- CLEANLINESS CONTROL
- WORK PLATFORMS

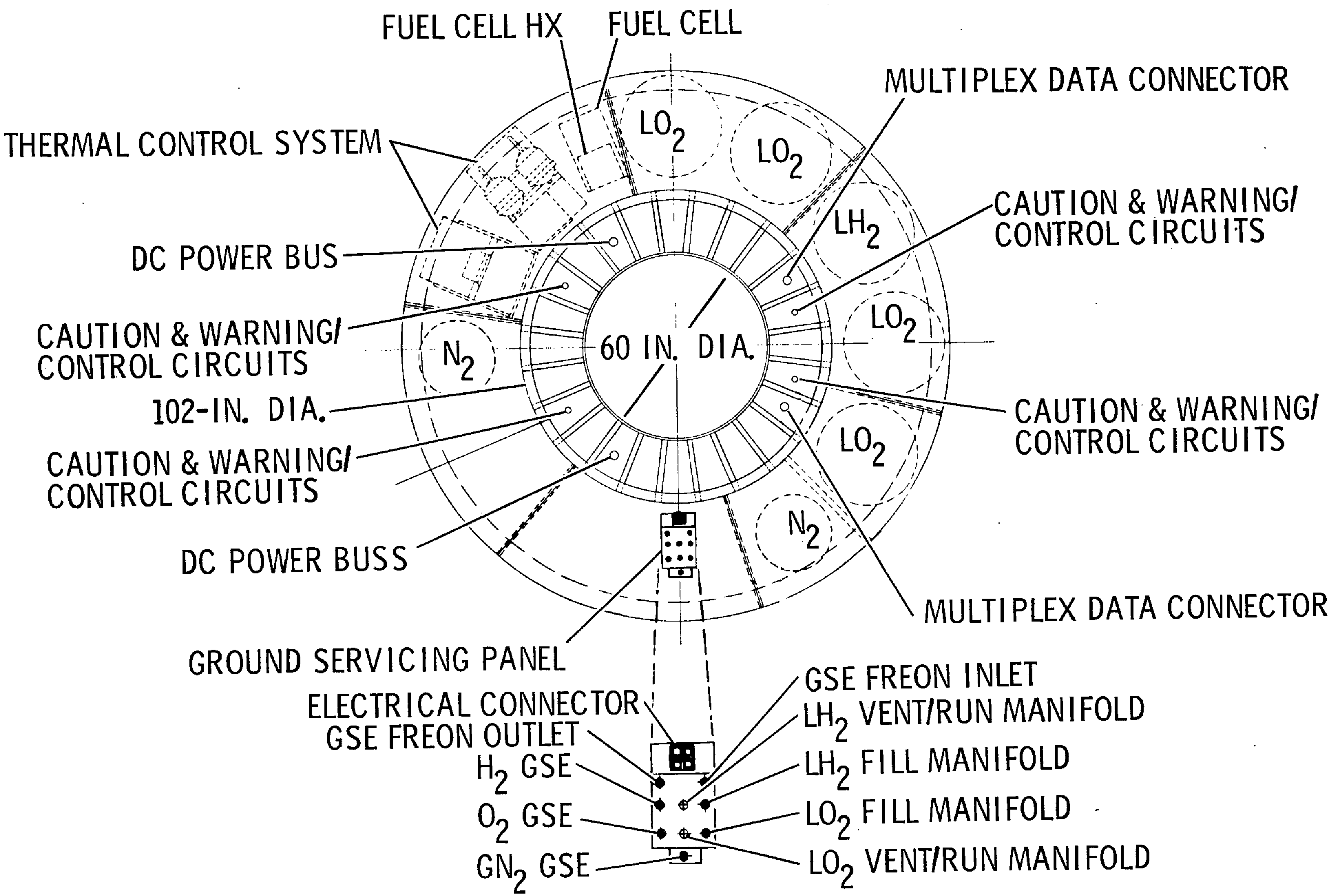
72-1686

The Sortie RAM has several functional interfaces with the shuttle orbiter; i.e., electrical power, data communications, caution and warning (C&W), and controls associated with C&W. Shuttle electrical power may be used during ascent/entry and serves as a backup source during orbital operations. Redundant buses are provided. RAM relies entirely upon the orbiter for communications and data transmission to earth. This is accomplished through redundant connections to the orbiter multiplex data system. A number of redundant hardwired circuits are provided for C&W signals from RAM to the orbiter crew and for associated emergency, safety control purposes.

A number of ground servicing functions are required by RAM while on the launch pad. Some are also used following return landing before RAM is removed from the orbiter cargo bay and may also be used during other ground operations, as necessary. Electrical power is provided for use before the RAM and orbiter systems are started. A ground cooling loop is used to absorb RAM heat until T-5 seconds. Cryogenic oxygen and hydrogen tanks and gaseous nitrogen tanks are filled on pad. They are also drained following landing. Gaseous makeup oxygen may be supplied to RAM on pad and excess gaseous hydrogen vented from the fuel cells. The RAM ground servicing connections are disconnected from the orbiter interface panel before RAM is deployed from the cargo bay for operations and remotely reconnected following return to the cargo bay. The ground services are provided from GSE through an umbilical arm to a payload service panel on the side of the orbiter.

Also shown in the illustration are equipment items located on the forward conical bulkhead of RAM between the shuttle attachment structure and the radiator/meteoroid bumper skirt. As noted, the shuttle interfaces, except the GSE functions, are located within the pressurized volume in an annular area approximately 21 inches wide.

SHUTTLE INTERFACE
Sortie Mission



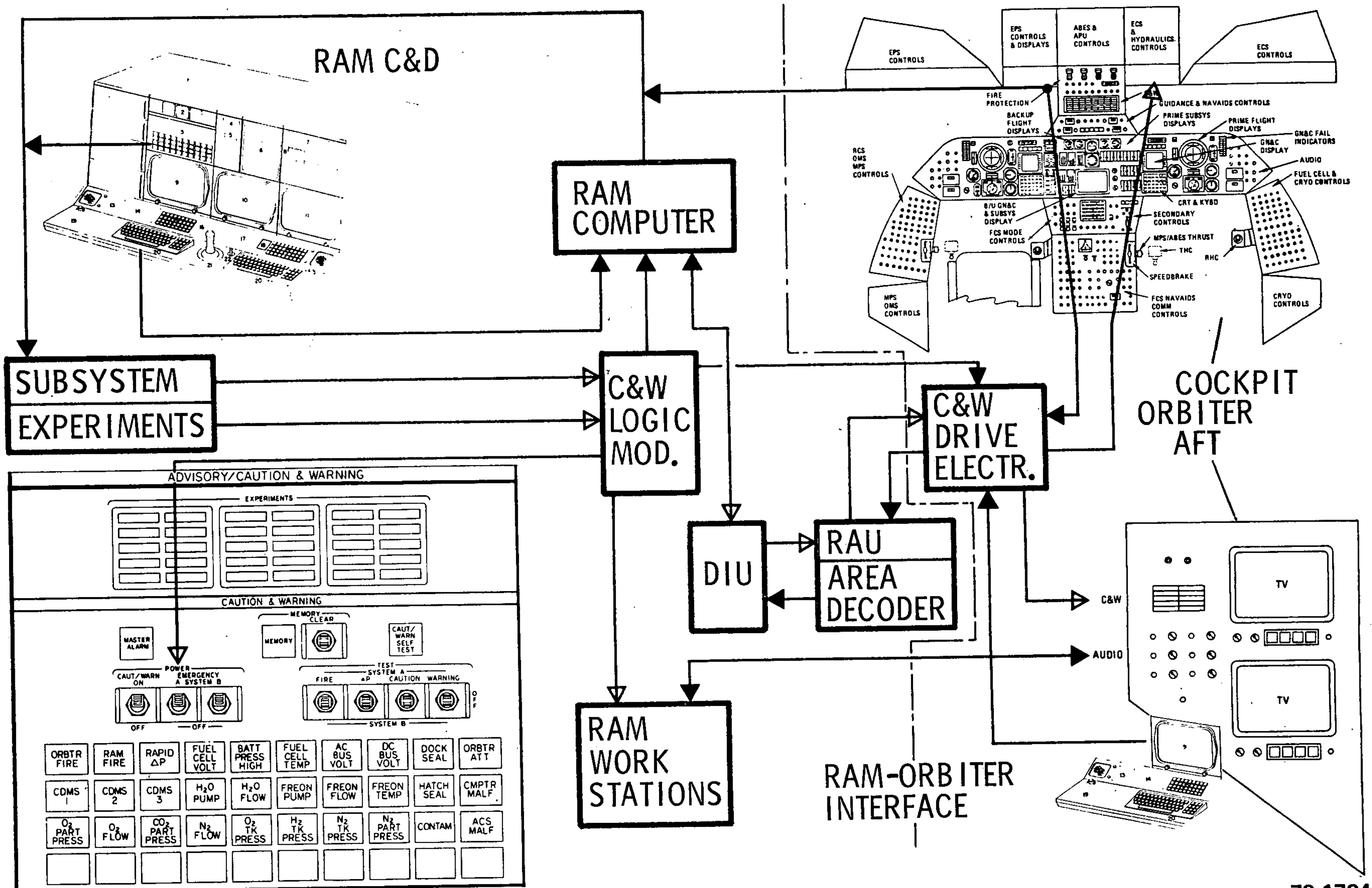
72-1703

CAUTION & WARNING
RAM/Shuttle Interface

The C&W system performs three basic functions: (1) detects alarm conditions; (2) generates appropriate electrical signals for alarms; and (3) generates electrical signals to initiate reaction to an alarm.

The C&W system interfaces and is compatible with the orbiter by means of several individual interface points. The RAM C&W logic module generates alarm signals that are hardwired to all RAM C&W displays and to the orbiter C&W displays. Command and control action from the orbiter commander is hardwired to the RAM subsystems and payload experiments. Continuous C&W display and control activity is implemented by an interface unit (consisting of a DIU, RAU, and area decoder) which connects the RAM and orbiter multiplex systems and allows asynchronous operation of both systems. Additionally, the audio intercom provides communication to support RAM/orbiter crew interaction during C&W situations.

CAUTION & WARNING
RAM/Shuttle Interface

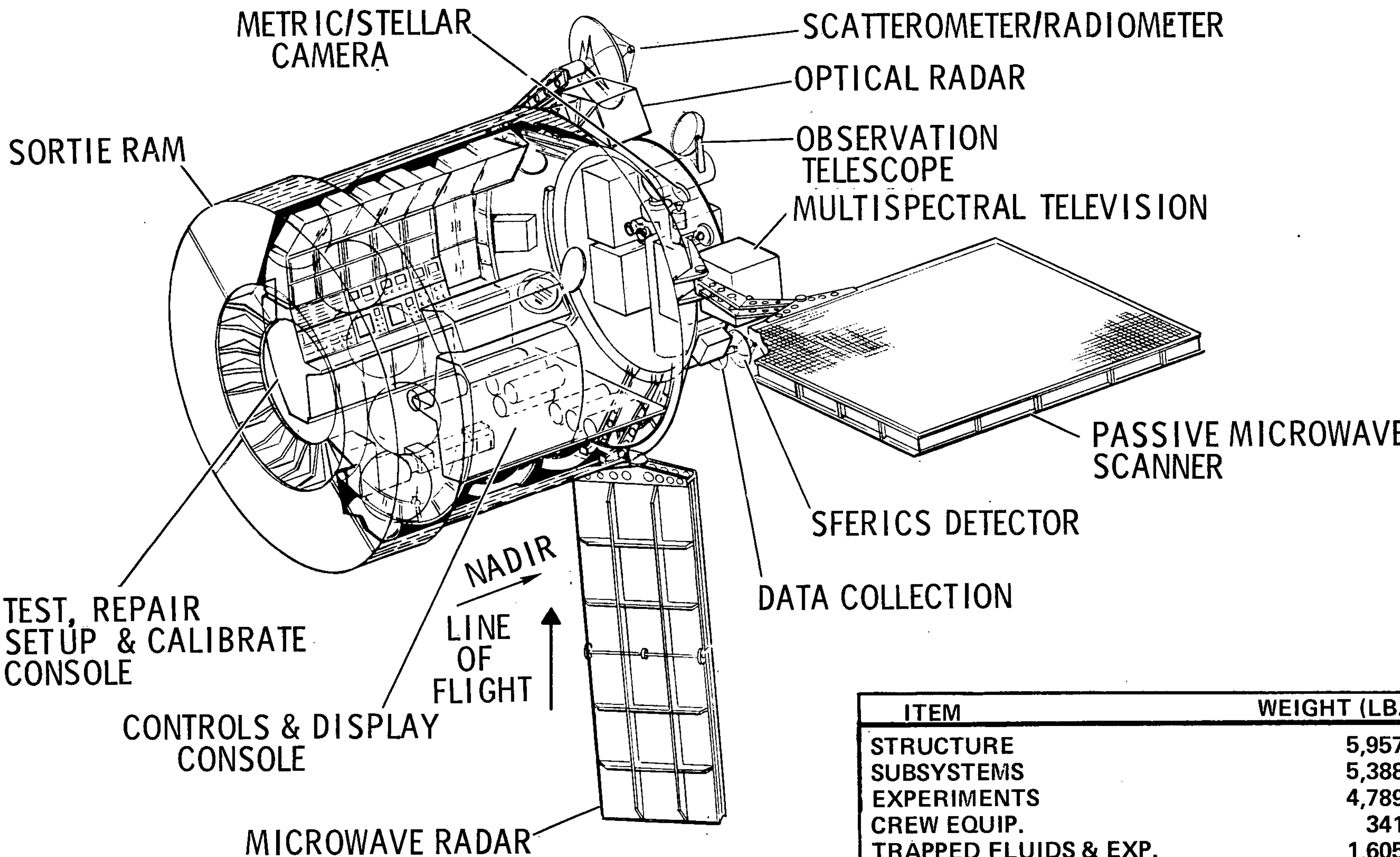


72-1724

Integration of a typical Earth Observations sortie payload E1S1O into the sortie RAM is depicted. Characteristic design drivers are the internal viewing instruments and the large external sensors, such as the passive microwave scanner and the microwave radar antenna. Experiment test, repair, setup, and calibration equipment is located along the right interior of the module, opposite the integrated control and display console.

The 102-inch diameter sensor mounting pressure bulkhead is a bolt/seal attachment to the aft end of the sortie RAM, replacing the standard domed end. Unique to this bulkhead are the four viewports located in the side of the bulkhead. These viewports allow stellar camera viewing in a direction perpendicular to the nadir. The external sensors are mounted to this bulkhead and the external flange of the 160-inch diameter kick ring on the pressurized RAM. In this way, the basic pressure shell of the RAM is not affected.

EARTH OBSERVATIONS
Sortie Mission Payload



PAYLOAD — E1S10

ITEM	WEIGHT (LB.)
STRUCTURE	5,957
SUBSYSTEMS	5,388
EXPERIMENTS	4,789
CREW EQUIP.	341
TRAPPED FLUIDS & EXP.	1,605
TOTAL	18,080

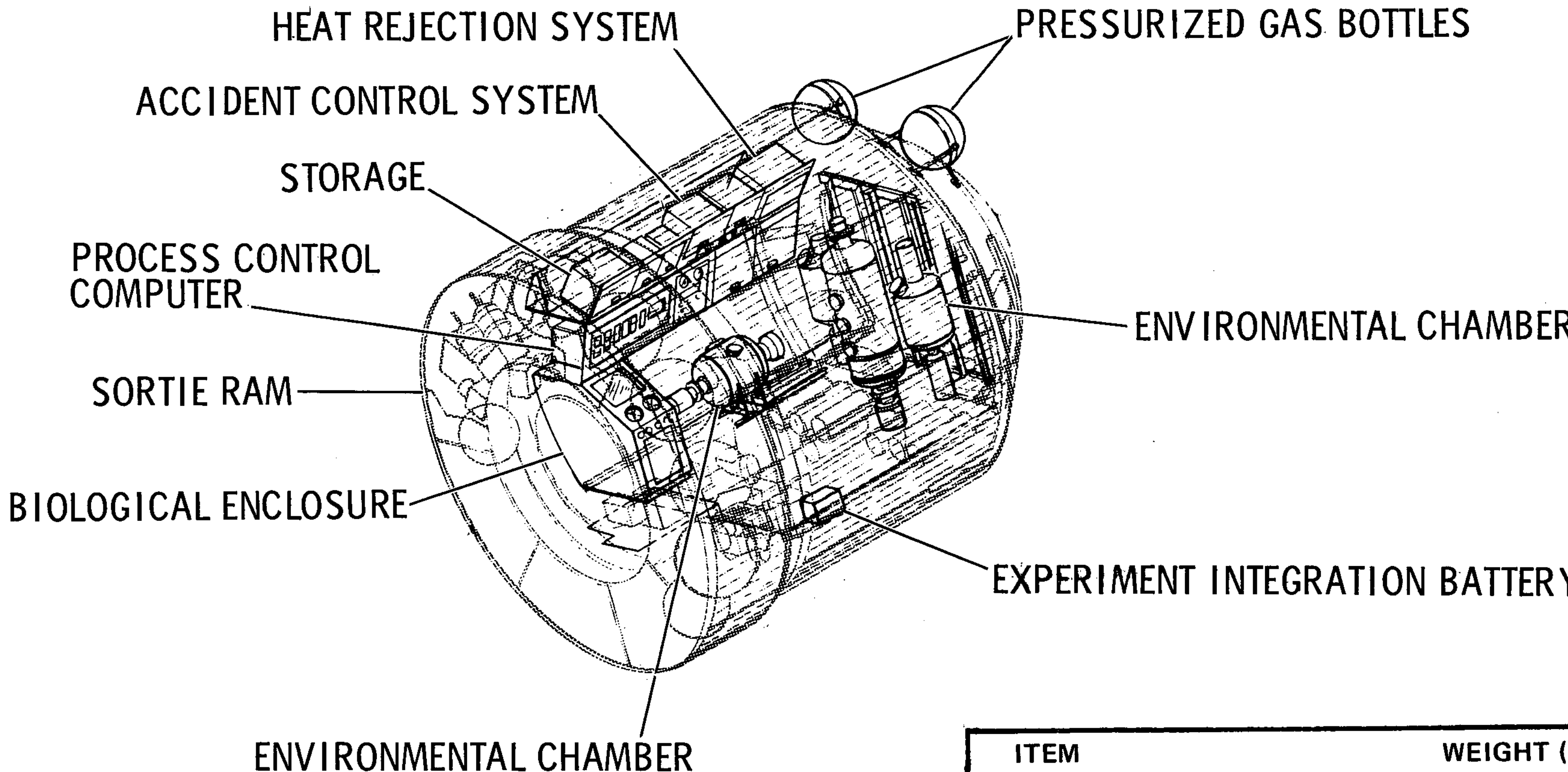
72-1676

Accommodation of the materials science payload M1S1E in a sortie RAM is shown. Experiment integration subsystem additional support is provided to meet peak electrical load demands with storage batteries, and environmental chamber requirements with stored bottle gases are supplied by the experiment.

The standard control and display console incorporates dedicated material science instrumentation and controls in the areas allotted for this purpose. Two of the environmental chambers are mounted vertically to a structural support rack. A structural track is used to provide a vertical guide to lift the chamber housing to gain access to the internal experiment equipment. The chambers mounted to removable racks on the floor have similar horizontal access provision to the internal equipment. All floor-mounted equipment is placed on standardized removable support channels. Experiment support equipment and stowage areas are located in the ceiling enclosure. The atmosphere supply and control system and the controlled atmosphere storage are mounted in the area directly above the environmental chamber.

One storage gas bottle required for the experiment is located externally in the conical bulkhead area using the same nitrogen type bottle installation as on the RSM.

MATERIALS SCIENCE
Sortie Mission Payload



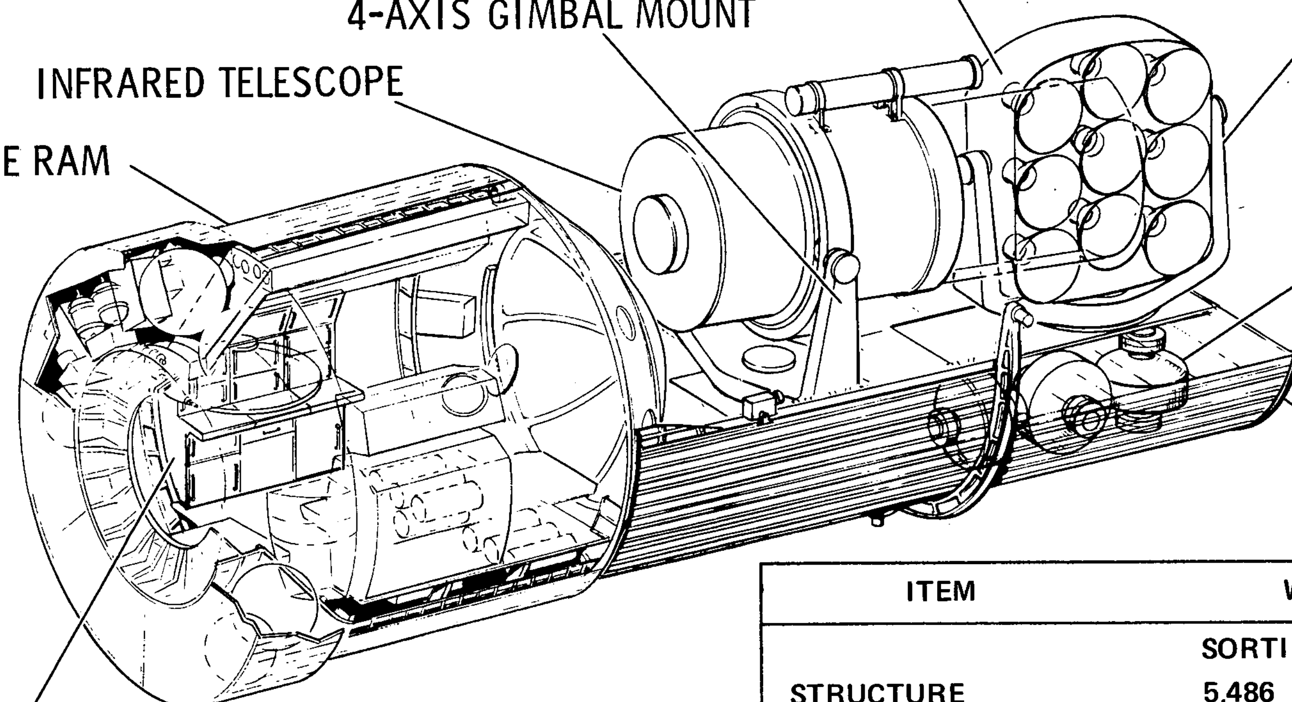
ITEM	WEIGHT (LB.)
STRUCTURE	5,486
SUBSYSTEM	5,566
EXPERIMENTS	3,100
CREW EQUIPMENT	341
RESIDUALS, RESERVES & EXP.	1,747
TOTAL	16,240

PAYLOAD — M1S1E

72-1677

RAM elements used for the integration of the sortie Astronomy payload A8S1Z illustrated opposite are the sortie RAM and pallet. The pallet attaches to the aft end of the sortie RAM at the outer flange of the 160-inch diameter kick ring. A basic domed end bulkhead is used. The experiment equipment racks are installed in the forward right side, opposite the integrated control and display console. The IR telescope and high-energy spectrometer/polarimeter array are each mounted on a gimbal attached to the pallet. Each gimbaled sensor is mounted to a plate structure, which is then installed in the pallet. The three add-on control moment gyros are attached to the underside of the aft plate.

ASTRONOMY
Sortie Mission Payload



ITEM	WEIGHT (LB.)	
	SORTIE RAM	PALLET
STRUCTURE	5,486	1,894
SUBSYSTEM	4,739	1,761
EXPERIMENT	1,658	7,589
CREW EQUIPMENT	341	
RESIDUALS, RESERVES & EXP.	1,725	
SUBTOTAL	13,949	11,244
TOTAL	25,193	

72-1678

C-3

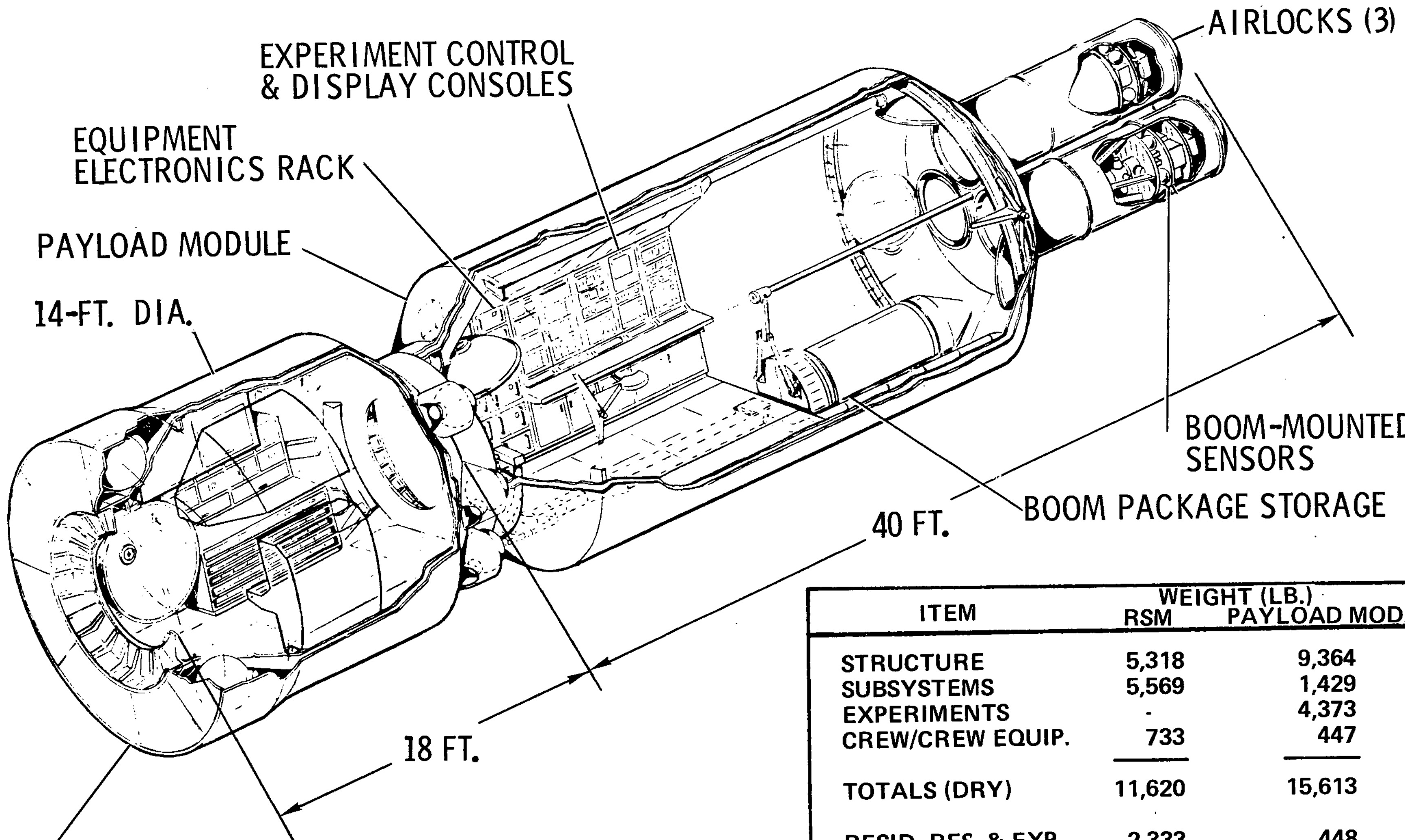
PHYSICS PAYLOAD
Advanced Sortie Mission

This is a combined space and plasma physics group of experiments. Illustrated is how this payload P5S1B would be integrated into a 32-foot RAM payload module.

This group of experiments requires three airlocks from which three variable-length booms, with end-mounted sensors, can be simultaneously deployed. Since these sensor packages must be changed and/or serviced during a seven-day sortie mission, it is necessary that the boom systems be retractable and that the boom-sensor packages be removable from the airlock into the pressuirzed module. The size of these combined boom/sensor packages, plus the volume required for the crew to maneuver around the packages, dictates that approximately 50% of the module be open area. The remaining volume in the module is symmetrically arranged to provide the necessary control/display consoles and sensor storage cabinets. Three standard viewports are provided on the conical section of the airlock/bulkhead, which enable circumferential monitoring of the deployed boom packages.

PHYSICS PAYLOAD

Advanced Sortie Mission



PAYLOAD P5S1B

ITEM	WEIGHT (LB.) RSM	PAYLOAD MOD.
STRUCTURE	5,318	9,364
SUBSYSTEMS	5,569	1,429
EXPERIMENTS	-	4,373
CREW/CREW EQUIP.	733	447
TOTALS (DRY)	11,620	15,613
RESID, RES & EXP.	2,333	448
TOTALS	13,953	16,061

72-1683 R

PRESSURIZED & UNPRESSURIZED RAMs – OPERATIONS

A.H. Ryan

- MISSION REQUIREMENTS
- RAM & SHUTTLE CAPABILITIES
- GROUND OPERATIONS
- FLIGHT OPERATIONS

72-1817

Major operations phases in a sortie mission turnaround cycle are: payload integration, prelaunch and launch, boost, and ascent to orbit on-orbit experimentation, RAM/payload securing for return, and RAM/payload maintenance and refurbishment.

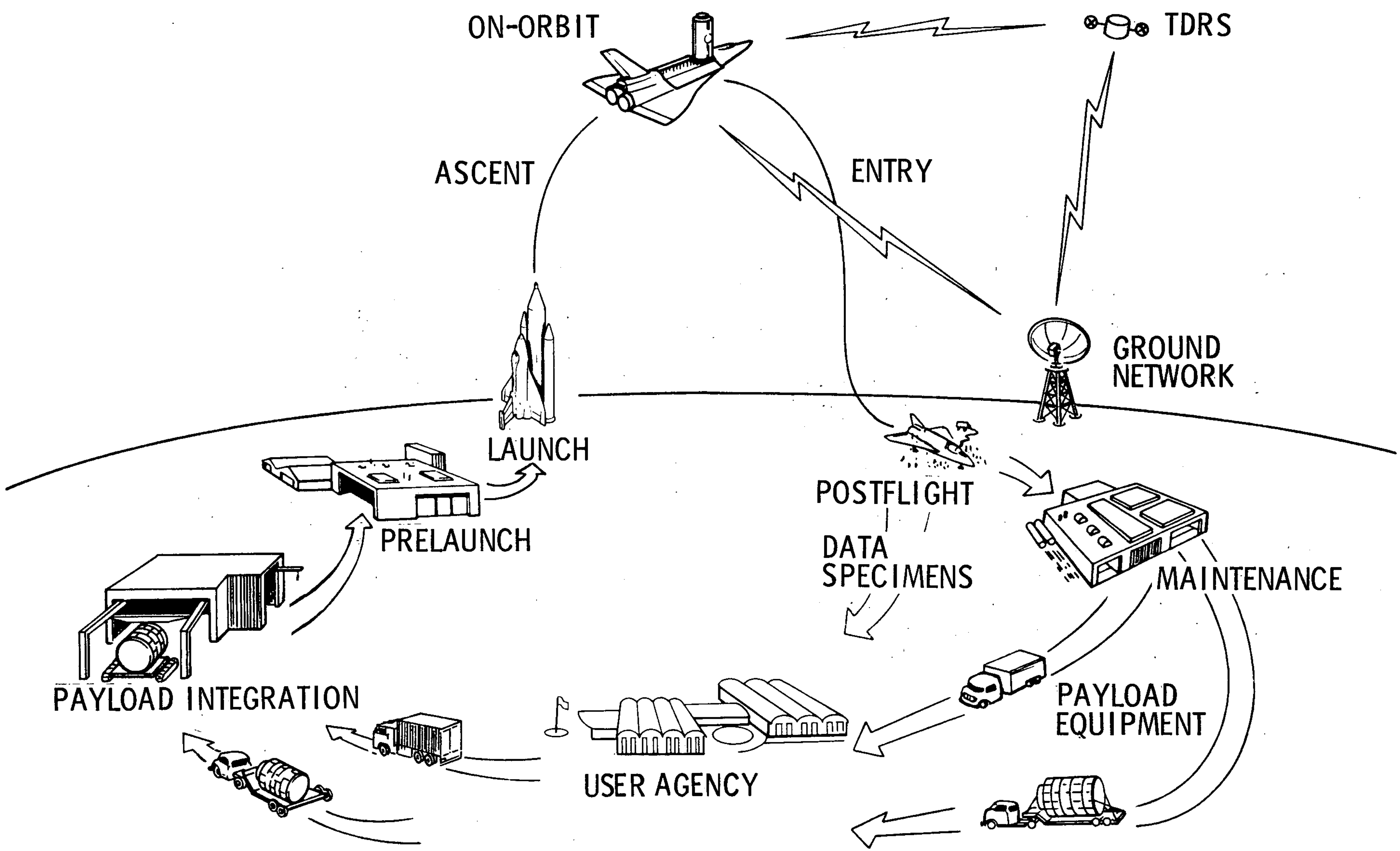
The prelaunch phase starts when payload integration is complete and a launch date has been set. Launch operations begin with transportation of the shuttle to the launch pad, verification of shuttle/RAM readiness for liftoff, loading of time-critical expendables, and shuttle liftoff.

During boost and ascent to orbit, RAM provides environmental protection and subsystem resources (electrical power, thermal control, etc.) to the payload. After reaching orbit, RAM is deployed from the orbiter cargo bay, if required. RAM subsystems and payload operations are then checked out in preparation for the on-orbit experiment period.

At the conclusion of the expermentation period, the payload and RAM are prepared by the payload crew for return to earth. After landing, the orbiter is safed, time-critical data removed from RAM and delivered to the user, and the RAM removed from the orbiter and delivered to the RAM maintenance/refurbishment facility.

RAM and its payload are repaired and maintained, as required. Sortie missions provide the capability for rapid turnaround and reflight of the same payload housed in a sortie RAM or a payload module, and for rapid turnaround of RSM subsystems in support of multiple RAM payload modules. After and maintenance, RAM is placed in storage or delivered to the payload integrated facility for preparation for the next flight.

SORTIE MISSION OPERATIONS

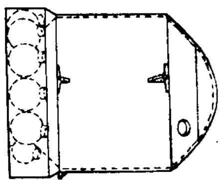
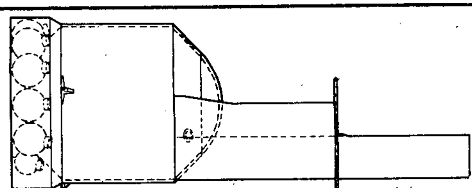
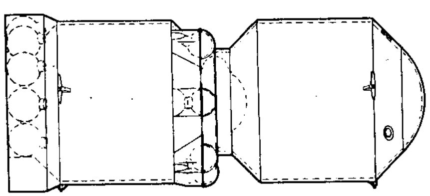
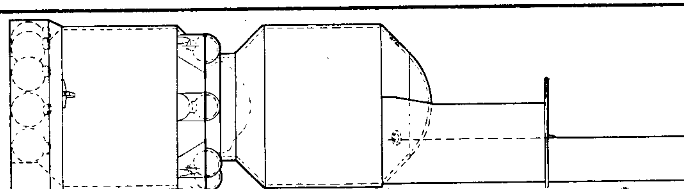


72-1713

SORTIE MISSION PAYLOAD IMPLEMENTATION

Sortie mission payloads are accommodated in the four RAM element configurations shown. The sortie RAM and sortie RAM/pallet provide versatile accommodation for early RAM payloads. Basic requirements satisfied by these elements are minimum cost, operational orbit flexibility (due to relatively low launch weight), and payload accommodation for experiments conducted by two payload crewmen. Beside accommodating sortie mission payloads, the sortie RAM provides servicing support in the shuttle-supported free-flying RAM servicing mission and is convertible to an RSM or payload module to support and accommodate later mission RAM payloads. The addition of a pallet to the sortie RAM provides additional area for mounting large items of experiment equipment that do not require a pressurized enviornment. The RSM/payload module and RSM/payload module pallet element configurations accommodate later mission payloads where more advanced and complex experiments are conducted during two shift operations by up to six payload crewmen.

SORTIE MISSION PAYLOAD IMPLEMENTATION

RAM ELEMENTS	PAYLOAD DISCIPLINE APPLICATION	REQUIREMENT
 SORTIE RAM	ZERO-g: MATERIAL SCI. LIFE SCIENCE TECHNOLOGY PHYSICS/CHEM. EARTH MEAS: EARTH OBS. COMM/NAV SPACE PHYS.	EARLY MISSIONS MINIMUM COST ORBIT FLEXIBILITY PAYLOAD CREW OF 2 FREE-FLYER SERVICE
 SORTIE RAM/PALLET	CELESTIAL OBSERVATIONS ZERO-g: TECHNOLOGY	EARLY MISSIONS EXTERNAL MOUNTING
 RSM/PAYLOAD MODULE	ZERO-g: MATERIAL SCI. LIFE SCIENCE TECHNOLOGY PHYSICS/CHEM. EARTH MEAS: EARTH OBS. COMM/NAV SPACE PHYS.	LATER MISSIONS PAYLOAD CREW OF 6 2 SHIFT OPERATION
 RSM/PAYLOAD MODULE/PALLET	CELESTIAL OBSERVATIONS ZERO-g: TECHNOLOGY	LATER MISSIONS EXTERNAL MOUNTING

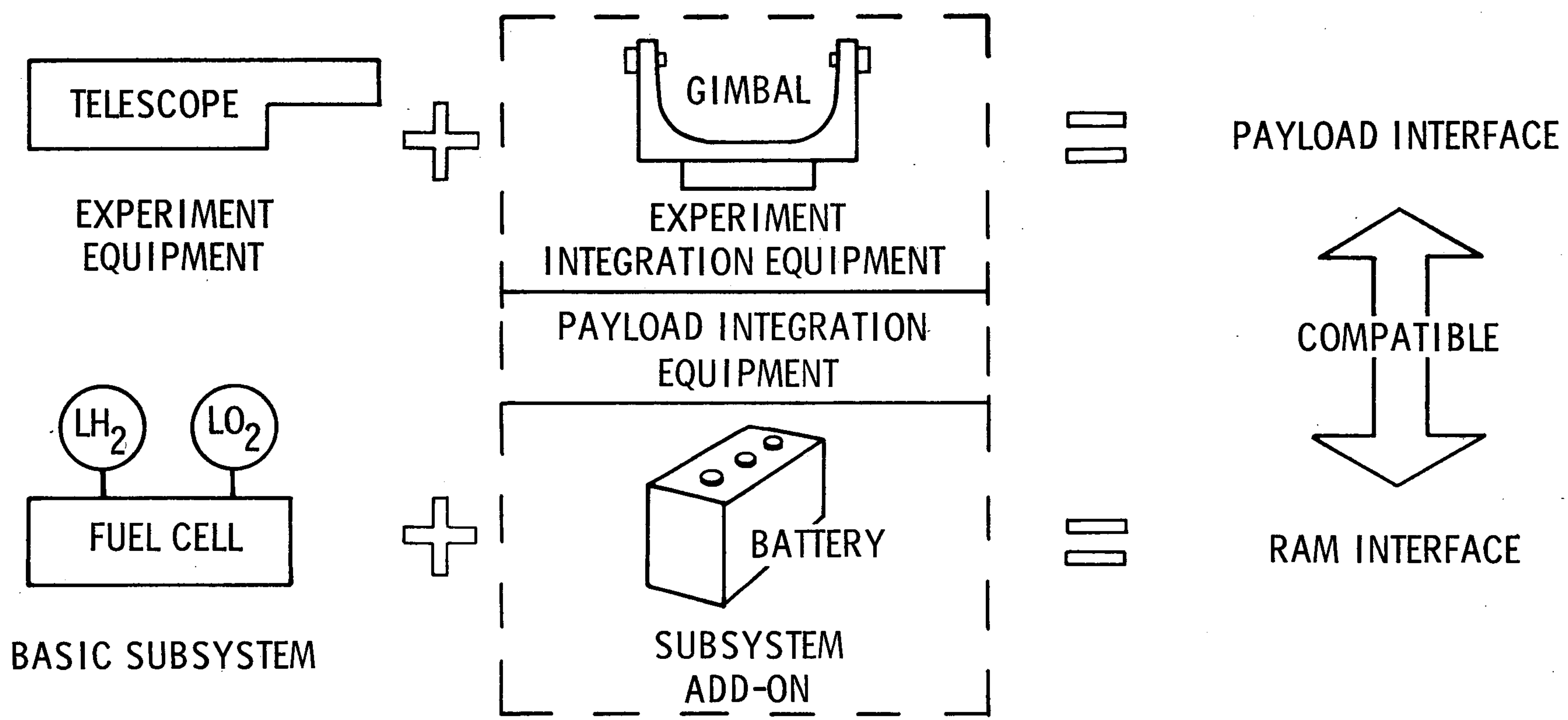
72-1715 R

Differences between experiment equipment requirements and RAM subsystem capabilities are bridged by payload integration equipment. Payload integration equipment includes: (1) experiment integration equipment that adapts the experiment to RAM mission and operational modes – experiment plus experiment integration equipment defines the interface presented by the payload to RAM; and (2) subsystem add-ons which are modular additions to the basic RAM subsystems – basic RAM subsystems plus subsystem add-ons define the interface presented by RAM to the payload.

Experiment integration equipment items are not generally specified in experiment definitions (as derived from the Blue Book) since equipment definitions could apply to mission modes other than RAM. Basic subsystem capabilities (without add-ons) were established following an analysis of experiment requirements and subsystem tradeoffs. A primary consideration in the tradeoffs was to satisfy a maximum number of payload requirements without an excessive subsystem capability level that would be usable for only a few payloads. Since payload requirements vary widely the difference between basic subsystem capabilities and payload requirements is filled by subsystem add-ons.

Payload integration equipment varies from payload to payload since it is dependent upon payload characteristics and required levels of resources. Typical examples of experiment integration equipment are contamination monitoring and protection devices, gimbals, etc. Typical examples of subsystem add-ons are CMGs, experiment-peculiar sensor bulkheads, etc.

INTERFACES & PAYLOAD INTEGRATION EQUIPMENT



TYPICAL PAYLOAD INTEGRATION EQUIPMENT

EXPERIMENT INTEGRATION EQUIPMENT	• CONTAMINATION MONITOR /PROTECTION • GIMBALS • BOOMS • FINE THERMAL CONTROL
SUBSYSTEM ADD-ONS	• CMG • CLOSED-CIRCUIT TV • SENSOR BULKHEAD • PEAKING BATTERY

72-1727

Payload integration operations are required to install a payload in a RAM and verify payload-to-RAM compatibility and readiness to enter prelaunch operations. Two major tasks are involved in payload integration: payload installation, and integrated test.

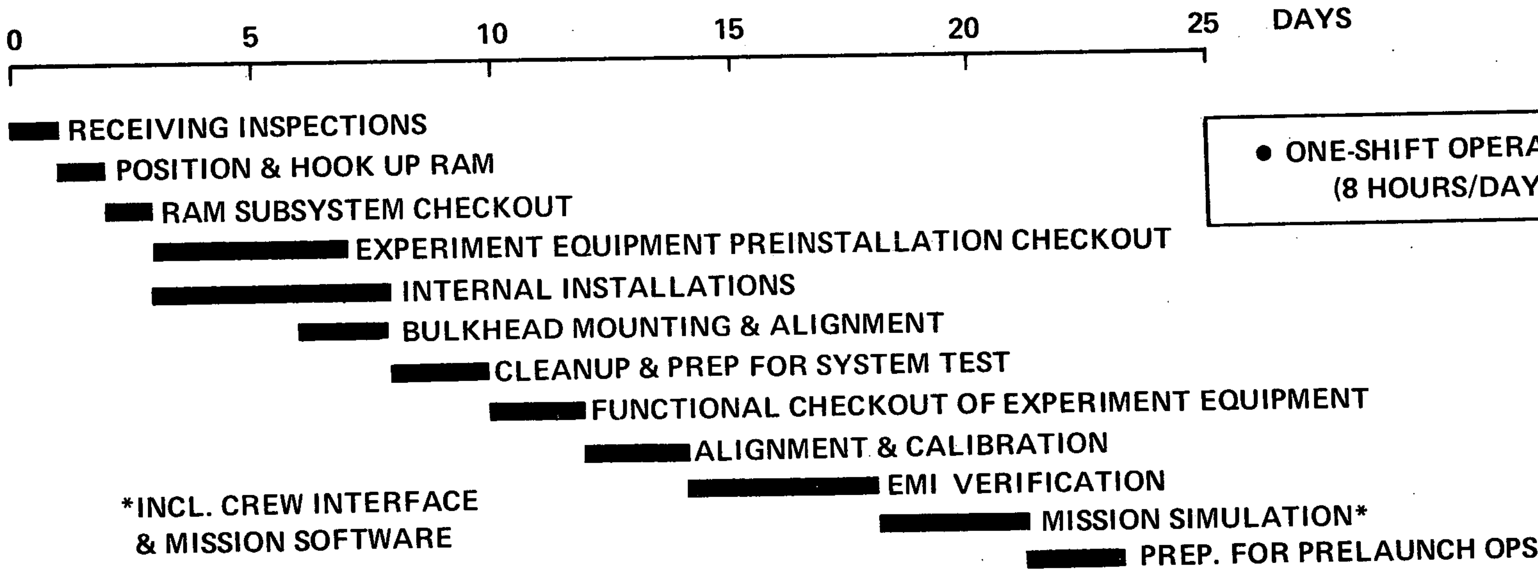
The example shown here is for a representative communications/navigtation payload, which is to be accommodated in a sortie RAM. The sortie RAM is received from the maintenance operations with payload equipment from the preceding mission removed. The new set of payload equipment is received at the payload integration facility and has completed production acceptance.

The major item of epxierment integration equipment is a flat-end bulkhead with mounting provisions for a one-meter parabolic antenna, a boresight telescope, and a subsatellite launch adapter and two subsatellites. These items, with the exception of the subsatellites, are mounted and aligned before attaching the bulkhead to RAM. Simultaneously, the major internal installations (receivers, transmitters, instruments, etc.) are made. The bulkhead is then mated to the RAM while final internal installations are completed. Cleanup and servicing in preparation for system test is accomplished next, followed by functional checkout of the installed equipment, final alignment, adjustment, and calibrations as necessary.

Integrated system test consists of two phases. Because of the nature of the equipment in the payload, the first phase is an electromagnetic compatibility test and demonstration. The second phase consists of a mission simulation that serves the multiple purposes of crew interface compatibility verification, final software verification and verification of overall payload/RAM/shuttle compatibility.

PAYLOAD INTEGRATION OPERATIONS
Typical Communications/Navigation Payload

PAYLOAD INSTALLATION	INTEGRATED TEST
• PREINSTALLATION CHECKOUT • INTERNAL INSTALLATIONS • BULKHEAD/SENSOR ASSEMBLY	• RAM/PAYLOAD COMPATIBILITY • MISSION SIMULATION



• ONE-SHIFT OPERATIONS (8 HOURS/DAY)

*INCL. CREW INTERFACE & MISSION SOFTWARE

72-1717

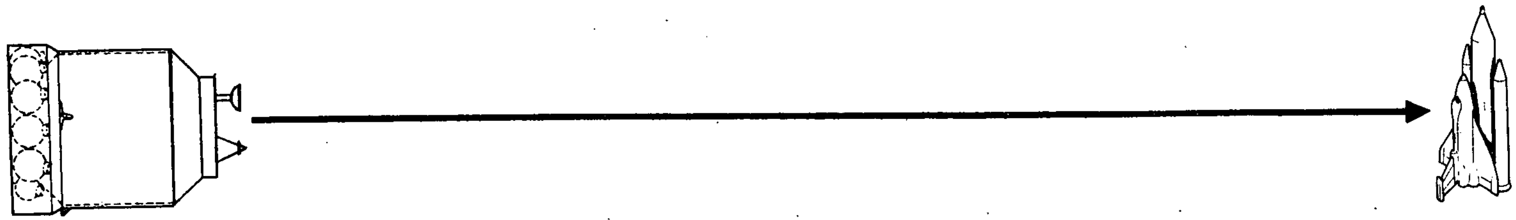
During prelaunch and launch operations RAM and its payload are prepared for launch by the shuttle. For the Communications/Navigation paylaod considered, the prelaunch/launch phase is about three weeks long, most of which is paced by shuttle operations.

When the sortie RAM with its installed payload arrives from payload integration, it is placed in a variable-attitude weight and balance fixture and weighed in two different attitudes. Upon completion of the weight and balance checks, the subsatellites are installed on the end bulkhead launcher assembly. while servicing of non-time-critical items is accomplished. Servicing includes spare LiOH canisters, filters, water, magnetic tapes, microfilm library, crew personal kits, photographic film, etc. Using the sortie RAM onboard checkout capability, a final check of subsystems and paylaod equipment is accomplished to ensure readiness for orbiter mate.

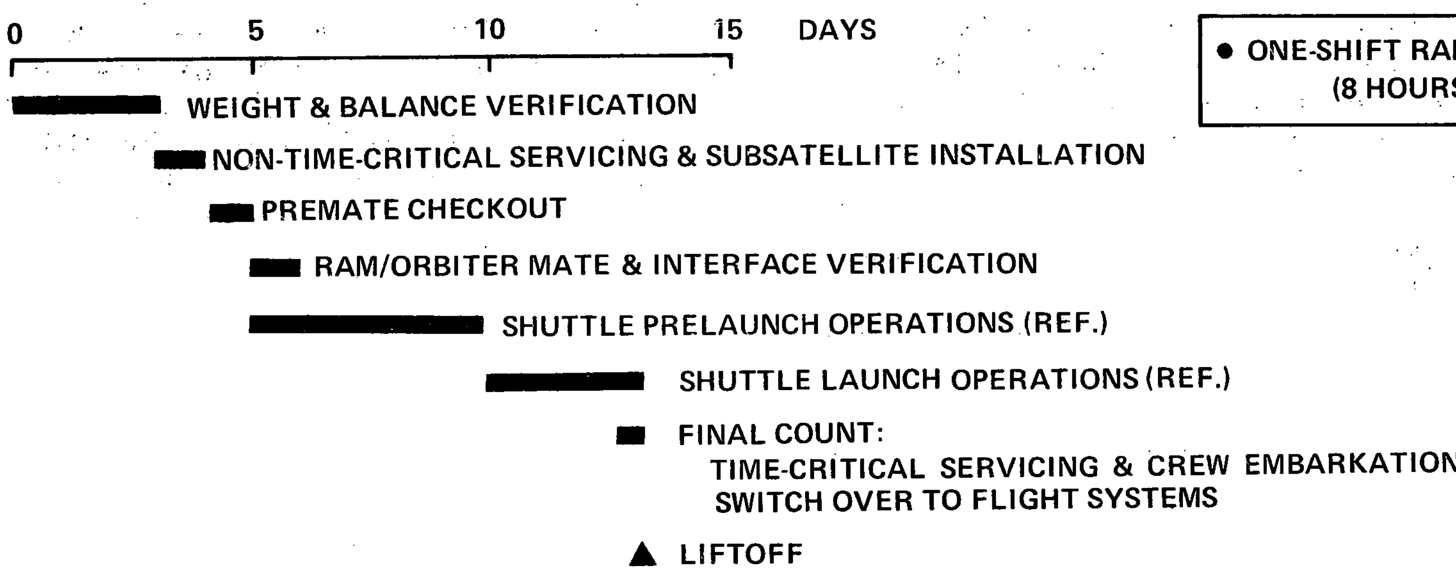
The RAM is then transported to the orbiter maintenance facility, RAM protective covers are removed and the RAM is installed in the orbiter payload bay while the orbiter is in the horizontal attitude. The various structural interfaces are latched and verified and two sets of utility interfaces connected – one set through the docking interface, the other between RAM and orbiter umbilical panel. Shuttle prelaunch operations terminate with the departure of the shuttle for the launch pad.

For the Communications/Navigation payload, there is no requirement for on-pad servicing, other than that required by RAM subsystems. RAM subsystem servicing consists of loading LH_2, LO_2, and 1,500-psi GN_2. The precise timing of these services depends upon the shuttle countdown timeline. RAM remains dependent upon ground support for electrical power and cooling until just before launch. The fuel cell is activated and checked out during the final countdown and RAM electrical loads are transferred to internally supplied power as late as possible before umbilical retraction.

PRELAUNCH/LAUNCH OPERATIONS
Typical Communications/Navigation Payload



PRELAUNCH	LAUNCH
• WEIGHT & BALANCE VERIFICATION • NON-TIME-CRITICAL SERVICING • PREMATE CHECKOUT & RAM/ORBITER MATE	• TIME-CRITICAL SERVICING • CREW EMBARKATION • SWITCH OVER TO FLIGHT SYSTEMS



• ONE-SHIFT RAM OPERATIONS (8 HOURS/DAY)

72-1718

MAJOR SORTIE MISSION REQUIREMENTS

RAM mission requirments have been derived from an analysis of RAM payload operations; major sortie mission requirements are summarized in this chart. Nominal sortie mission duration is seven days; longer missions are possible with add-ons to basic shuttle/RAM resource capabilities. Orbit requirements are consistent with payload requirements and shuttle capability. Acceleration-sensitive payloads may require a shuttle drift mode with restrictions on ACPS firing and crew motion. Contamination sensitive payloads employ countermeasures such as control moment gyros (CMGs) for attitude control, restricted ACPS operation, and contamination covers. Payloads sensitive to high-energy radiation are placed in low-radiation orbits and employ radiation shielding.

Orientation requirements vary by payload. Earth measurements payloads typically require an earth orientation; an inertial or solar orientation is required for celestial observation payloads. RAM (or experiment integration equipment) provides pointing capability beyond shuttle capability. Power generation (or distribution), data storage, and heat rejection capability are required for all payloads and are satisfied by RAM subsystems with subsystem add-ons as necessary. The RAM-to-ground communications link is through the shuttle to TDRS/MSFN. Payload crew sizes range from two to six with the shuttle providing habitability for two crewmen; additional crewmen (up to four) are housed in an RSM.

MAJOR SORTIE MISSION REQUIREMENTS

CHARACTERISTIC	REQUIREMENTS	IMPLEMENTATION
MISSION DURATION	7 DAYS (NOM.) >7 DAYS	SHUTTLE/RAM RESOURCES ADD-ONS
ORBIT		
ALTITUDE INCLINATION	100 - 400 N. MI. 28.5 - 97°	SHUTTLE — ABES OUT (LAUNCH FROM CONT. U. S.)
ENVIRONMENT		
ACCELERATION CONTAMINATION	$<10^{-3}$ TO 10^{-5}g MINIMUM	SHUTTLE OPERATIONS RAM/SHUTTLE COUNTERMEASURES
RADIATION	$<10^{-3}$ RAD./HR. (ASTR)	ORBIT/SHIELDING
ORIENTATION	VARIOUS	SHUTTLE-COARSE (±0.5°)/RAM-FINE
PAYLOAD RESOURCES	POWER GENERATION DATA STORAGE HEAT REJECTION	RAM SUBSYSTEMS
COMMUNICATIONS	VOICE & NEAR REAL-TIME DATA	SHUTTLE TO TDRS/MSFN
PAYLOAD CREW	2 TO 6	ORBITER — 2 RSM — UP TO 4

72-1711

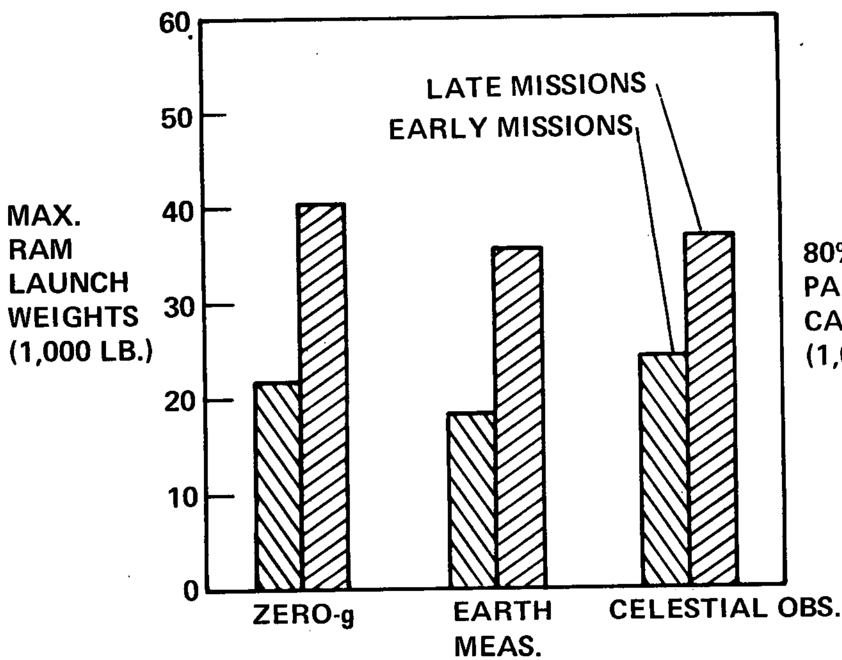
SORTIE MISSION CAPABILITY

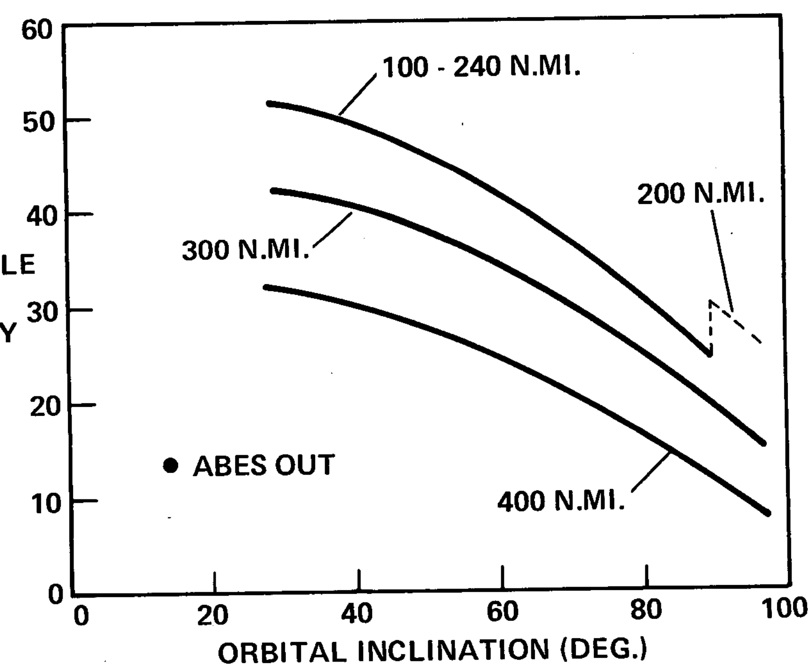
Sortie mission payload orbit requirements and the capability of the shuttle to deliver these payloads to the required orbits are summarized in the chart. Zero-g laboratories only require sufficient orbit altitude to provide a low-drag environment for the experiments over a seven-day mission. An orbit altitude of 120 n.mi. satisfies these requirements. Preferred earth measurement operating orbits have high inclinations for global coverage and low altitude for maximum resolution. Sortie mission celestial observation payloads prefer orbits with high altitude to maximize observation time and low inclination to minimize exposure to South Atlantic anomaly radiation. A near-polar orbit is preferred for the solar astronomy payload.

Maximum estimated launch weights for early and later mission configurations are shown. Shuttle payload capability (ABES out) in thousands of pounds (using RAM study guidelines of 80% capability available to RAM) is plotted for orbits of interest to sortie mission payloads. The discontinuity at 90 degrees inclination in the low-altitude performance curve is a result of offloading the shuttle orbital maneuver subsystem (OMS) tank for inclinations greater than or equal to 90 degrees. Shuttle payload capability is sufficient to deliver the maximum weight zero-g laboratory configurations to greater than the required 120-n.mi. altitude. Early mission earth measurements configurations can be delivered to preferred (polar) orbits while later mission earth measurements configurations can be delivered to an acceptable orbit in all cases. Early mission celestial observations configurations can be delivered to preferred orbits – sun synchronous at 200 n.mi. altitude in the most demanding case. Later mission celestial observations configurations can be delivered to acceptable orbits in all cases.

SORTIE MISSION CAPABILITY

PAYLOAD ORBIT REQUIREMENTS		
PAYLOAD TYPE	PREFERRED ORBIT	ACCEPTABLE ORBIT
ZERO-g	>120 N.MI. x ANY INCL.	>120 N.MI. x ANY INCL.
EARTH MEAS.	100 N.MI. x 50° - 90°	100 N. MI. x 50°
CELESTIAL OBS	200 - 400 N.MI. x 28.5° - 55°, 97°	200 - 270 N.MI. x 28.5° - 45°





72-1710

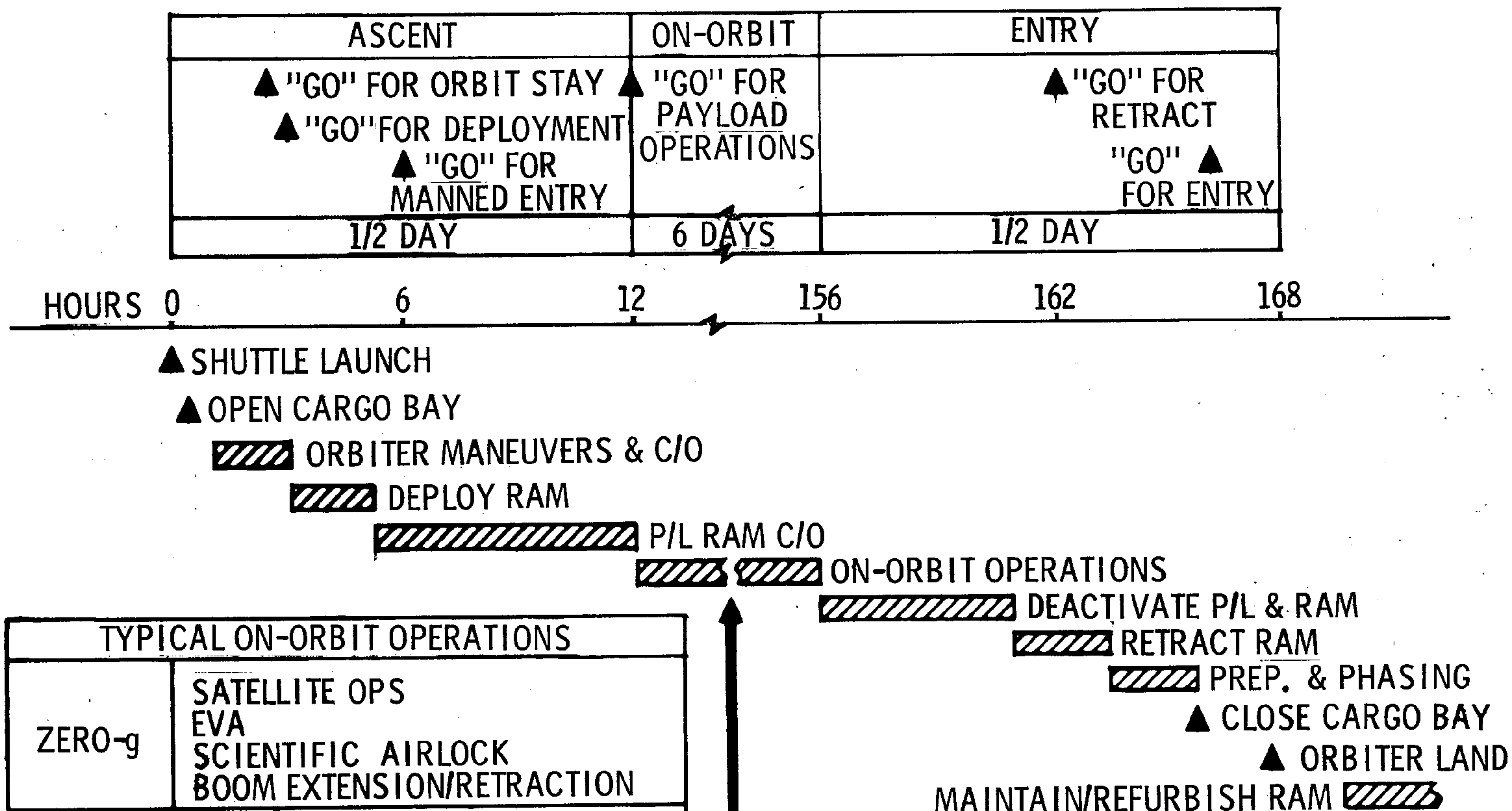
TYPICAL SORTIE MISSION FLIGHT OPERATIONS

Flight operations begin with the launch of the shuttle (the RAM crew is awakened at T-6 hours and boards at T-1 hour). After orbiter separation from the booster and insertion into the transfer ellipse orbit, the orbiter cargo bay doors open, exposing RAM thermal radiators for temperature control. A Hohmann transfer to circular orbit at the desired operational orbit altitude is completed at about 90 minutes into the mission. One hour is estimated for orbiter checkout. Following boost and ascent to orbit, RAM deployment (if required) from the orbiter cargo bay is accomplished by manipulator or pivoted mechanisms. Six and one-half hours are necessary for on-orbit RAM and payload checkout. After all checkouts have been completed satisfactorily, the "go" for payload operations is given. During the approximately six days of payload on-orbit operations, a two-man RAM crew works together typically on a one shift on/one shift off basis (12 hours work per day average). A four-man RAM crew typically works around the clock (two men per shift). About 2.5 hours per day are required for daily subsystems operations and maintenance tasks.

Following payload operations, six hours are typically needed to deactivate and safe RAM and the payload. RAM is then retracted into the orbiter cargo bay. Nominal orbiter earth return operations require about four hours for entry preparation and proper phasing for landing. Cargo bay doors are closed just before deorbit. Orbiter landing is indicated at 168 hours elapsed time from launch. Systems "go" at each major decision point (e.g., orbit stay, RAM deployment) is verified by use of caution and warning indications, checkout data, and visual checks before proceeding into the next operation.

Typical on-orbit operations are shown in the inset for zero-g, earth measurement, and celestial observation payloads.

TYPICAL SORTIE MISSION FLIGHT OPERATIONS



TYPICAL ON-ORBIT OPERATIONS	
ZERO-g	SATELLITE OPS EVA SCIENTIFIC AIRLOCK BOOM EXTENSION/RETRACTION
EARTH MEAS.	DEPLOY/STOW ANTENNAS, BOOMS ACPS HOLD DRIFT (NON-OBS. PERIODS) NAVIGATION UPDATE VENT/EMI CONTROL
CELESTIAL OBS	CMG SPINUP/SPINDOWN ACPS/CMG CONTROL TRANSFER CONTAMINATION CONTROL

72-1708

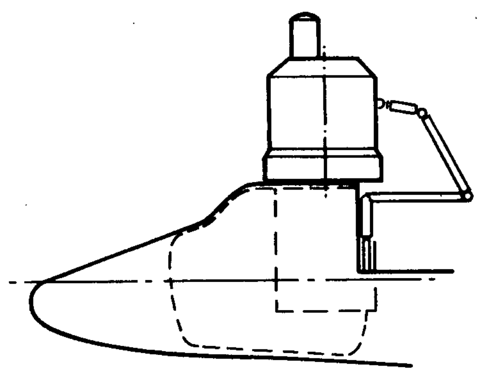
DEPLOYMENT OPERATIONS

Two alternative modes of RAM deployment are being considered for sortie missions: manipulator deployment, and pivoted deployment. The total deployment operation using manipulators takes about three hours and follows the general pattern of other RAM operations sequences, starting with readiness checks and concluding with verification to proceed to the next major phase. At least one orbiter crewman will be controlling the operation from an orbiter-located console, which has the capability for controlling and monitoring events, and maintaining audio contact with a RAM crewman who, at times, may be in the orbiter airlock. During the RAM traverse from the bay to the deployed position (approximately 45 minutes) the normal RAM-to-orbiter interface is broken. Safety analysis requires caution and warning and control of critical RAM functions during this period. A means of carrying orbiter power to RAM is also required for backup power to essential subsystems. The pivoted deployment mode is estimated to require about 75 minutes to complete the operation. The RAM-to-orbiter interface is not broken in this instance.

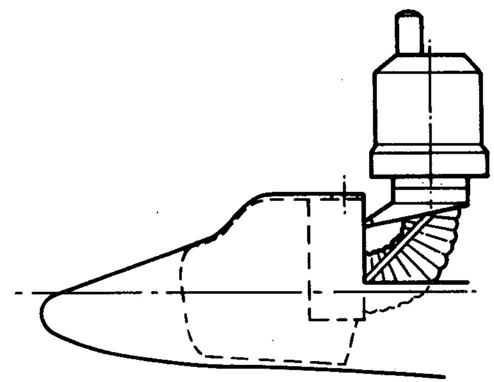
A comparison of the two methods reveals significant differences in both operational and safety areas. The impact of break/remake connections at the interface increases the manipulator mode checkout requirements to verify continuity of the interconnect functions and of RAM subsystem operations. RAM crew workload in support of these operations is also increased.

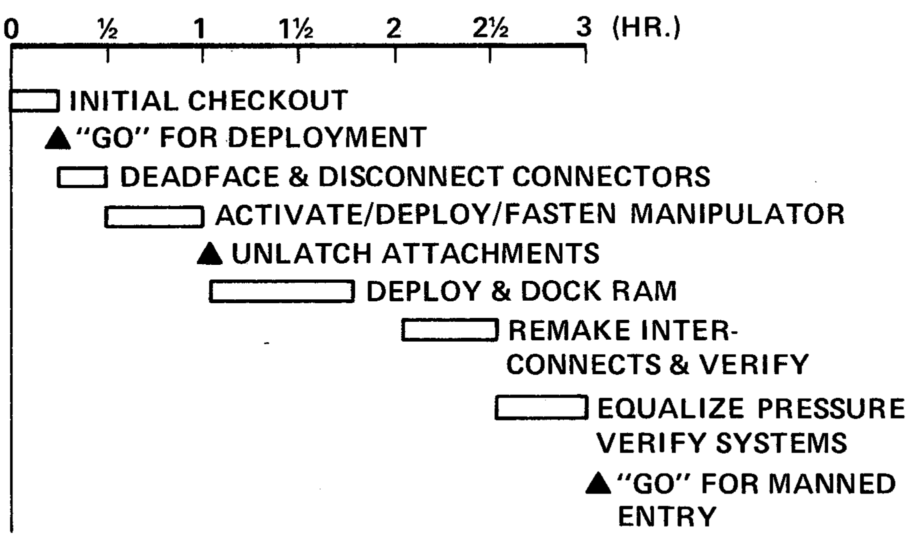
DEPLOYMENT OPERATIONS

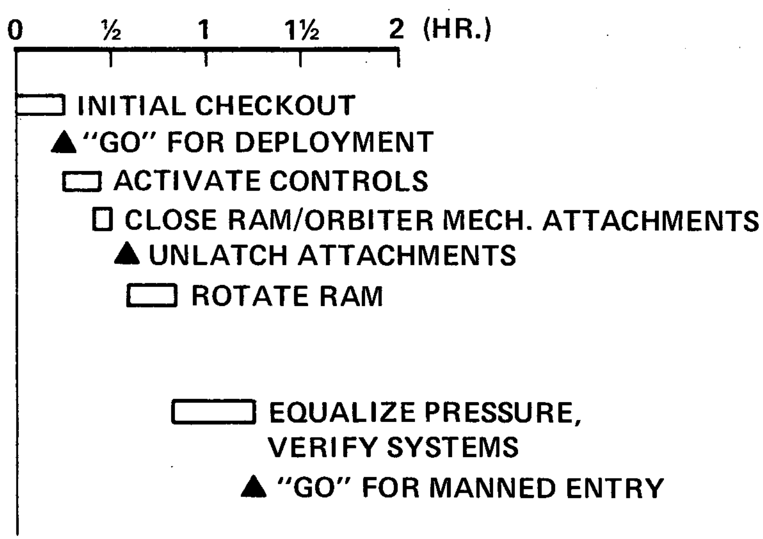
MANIPULATOR MODE



PIVOTED MODE







72-1728

ON-ORBIT ORIENTATION REQUIREMENT

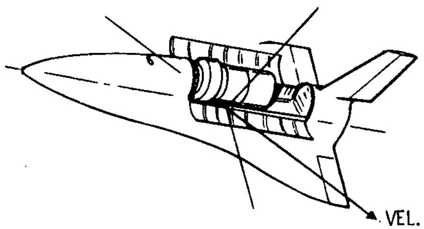
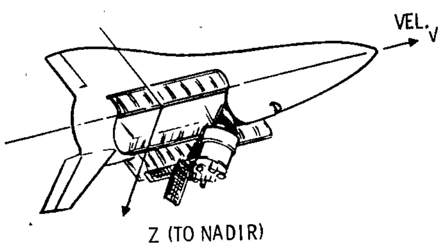
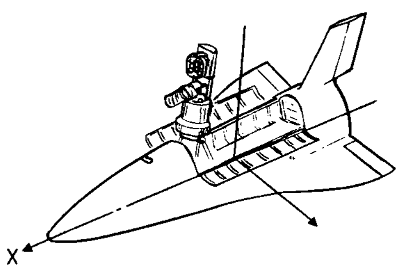
Orientation requirements for sortie payloads are conveniently categorized by major payload operations as discussed below.

ZERO-g LABORATORIES – Orientation for the material science, technology and life science laboratories in this category are driven by low acceleration requirements. The shuttle may have any orientation but must maintain acceleration levels less than 10^{-4}g and less than 10^{-5}g 95% of the time for life sciences payloads. These laboratories are insensitive to atmosphere contamination, but in the case of the life science laboratory a minimum radiation level must be maintained.

EARTH MEASUREMENT – Payloads include earth observation, physics and comm/nav disciplines. Orientation is driven by payload requirements to view the earth for durations of up to 30 minutes per orbit. The shuttle must orient its Z axis to the nadir to provide for viewing within + 60-deg of nadir. Sensors are sensitive to contamination and require contamination monitoring and countermeasures such as instrument protective covers and attention to location and operation of vents and shuttle ACPS.

CELESTIAL OBSERVATION – Orientation is driven by requirements for accurate celestial pointing for periods up to five hours. The shuttle stabilizes to +0.5 degree; this is augmented by RAM control moment gyros. The shuttle is oriented with the x-axis perpendicular to the orbit plane to minimize momentum accumulation. Viewing restrictions depend on the particular payload and celestial target. Sensors are sensitive to both contamination and high energy space radiation and require contamination monitoring and countermeasures. Celestial viewing is restricted to those periods in which the vehicle is under control of the CMGs.

ON-ORBIT ORIENTATION REQUIREMENTS

EXPERIMENT TYPE	ORBITER STABILIZATION	OTHER CONSTRAINTS
 ZERO-g LAB	ANY ORIENTATION ACCELERATION $< 10^{-4}$ g (LIFE SCIENCES $< 10^{-5}$ g 95% OF TIME)	INSENSITIVE TO ATMOSPHERE CONTAMINATION MINIMUM RADIATION
 EARTH MEASUREMENTS	Z TO NADIR POINTING ±0.5° (FOR PHYSICS ±5.0° CONTINUOUS) DATA TAKING 30 MIN./ORBIT	VIEWING ±60° FROM NADIR TARGET LIGHTING CONTAMINATION COUNTERMEASURES
 CELESTIAL OBSERVATIONS	X-POP POINTING ±0.5° FOR 0.1 - 5 HR. (NONPROPULSIVE STABILITY BY RAM)	VIEWING: > 45° - 90° FROM SUN > 30° - 60° FROM EARTH > 15° - 25° FROM HORIZON RADIATION $< 10^{-3}$ RAD/HR. CONTAMINATION COUNTERMEAS.

72-1714

CREW TASK ASSIGNMENTS

There are two types of RAM crew members: payload specialists, and mission specialists. The payload specialist is either the principal experimenter or the representative of the experimenter(s). He has prime responsibility to set up and conduct all experiment operations in a shirtsleeve environment, and direct and/or monitor experiments conducted externally to the pressurized RAM. He also assists in RAM housekeeping and subsystem operations under the direction of the mission specialist.

The mission specialist has prime responsibility for RAM, including housekeeping activities, maintenance of RAM subsystems and RAM/shuttle interfaces, and command of RAM operations during emergencies. He also assists the payload specialist in the conduct of experiments, performs EVA operations, and controls subsatellite flight trajectories.

The shuttle crew is responsible for overall operational command and safety of the shuttle/RAM system. They provide shuttle support where needed (i.e., orbiter orientation, venting control) to support mission goals and operate specific shuttle systems (i.e., manipulator) which directly support payload operations.

CREW TASK ASSIGNMENTS

TASK	RAM CREW RESPONSIBILITY		SHUTTLE CREW RESPONSIBILITY
	MISSION SPECIALIST	PAYLOAD SPECIALIST	
RAM HOUSEKEEPING	PRIME	ASSIST	INTERFACE SCHEDULING
SUBSYSTEM OPERATIONS	PRIMARY	ASSIST	INTERFACE MONITOR
EXPERIMENT OPERATIONS	ASSIST	SET UP – CONDUCT	SAFETY MONITOR
DEPLOYMENT (Dock/Undock)	MAKE/BREAK INTERFACES MONITOR SUBSYSTEMS	MONITOR EXPERIMENTS	COMMAND & CONTROL
EVA (Experiments)	PERFORM	MONITOR EXPERIMENT	SAFETY MONITOR
SUBSATELLITES (Experiments)	LAUNCH/RETRIEVE CONTROL	DIRECT EXPERIMENT	SAFETY MONITOR
EMERGENCIES	COMMAND (RAM)	AS DIRECTED	COMMAND (SHUTTLE/RAM)

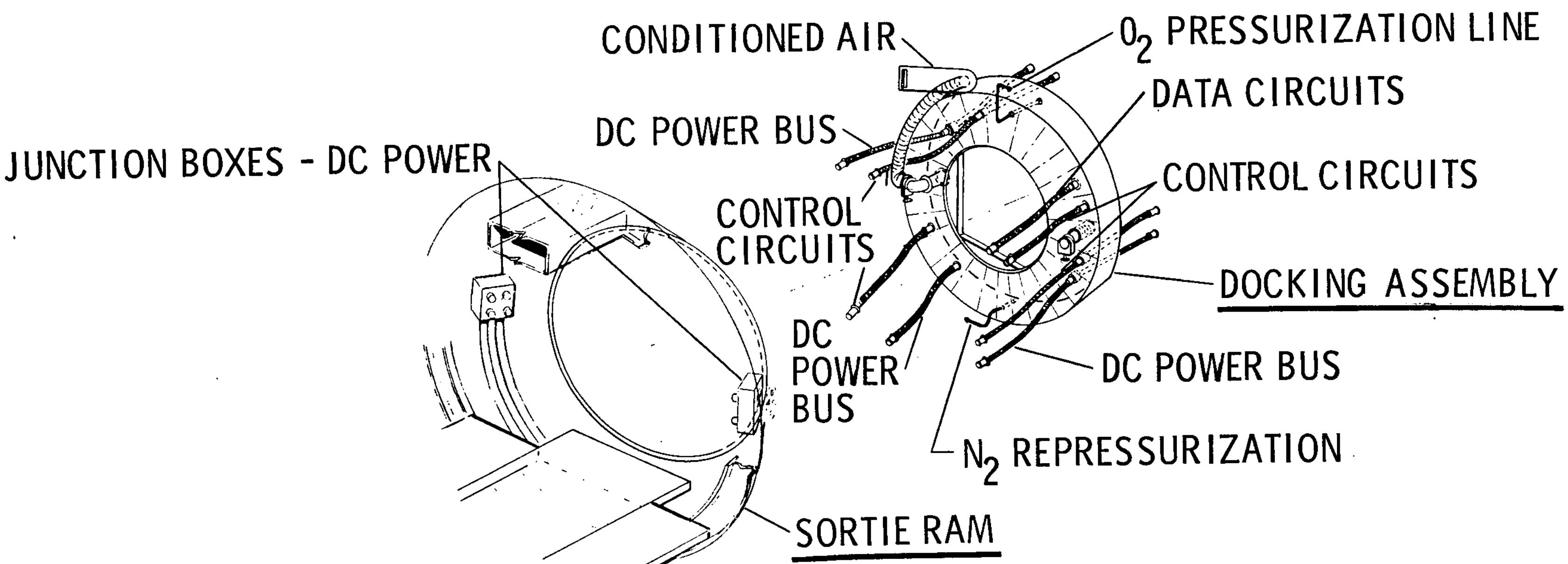
72-1709

As a cost-saving device in funding constrained programs, a single sortie RAM may be used for both free-flying RAM servicing and payload missions. In a typical case, sensors used during the previous sortie payload mission are removed from the aft RAM conical bulkhead along with the 102-inch diameter experiment-peculiar bulkhead. If the sortie RAM is scheduled to return to orbit with the same payload on the next mission following the servicing mission, internally mounted payload equipment is deactivated but not removed, unless calibration or some other servicing is required.

A preassembled docking/hatch assembly is installed at the 102-inch diameter flange and high-pressure gaseous nitrogen bottles with plumbing and micrometeoroid protection are installed. Operations internal to RAM include connecting air ducts, repressurization lines, etc., and loading the spares and installation/servicing equipment required for the mission. Following installation, integrated system tests are performed to verify the servicing configuration. It is estimated that 14 days (of one-shift operations) will be required to accomplish these removal/installation/test operations.

Servicing requirements include storage volume for experiment and subsystem equipment; quantities for a six-month service interval are shown. Experiment equipment quantities will vary with each payload; the quantities shown are representative of a worst-case free-flying RAM. Racks for mounting up to four propulsion modules (replaced by orbiter manipulator for the shuttle-supported free flyer) are made on the aft conical bulkhead of the Sortie RAM.

FREE-FLYING RAM SERVICING REQUIREMENTS & CONFIGURATION



FUNCTION/RESOURCE	REQUIREMENT
STORAGE LENGTH	5 FT. (MAXIMUM EQUIPMENT LENGTH)
STORAGE: – EXPERIMENT EQUIPMENT – SUBSYSTEM EQUIPMENT	88 CU.FT./2,100 LB. 25 CU.FT./900 LB. } 6-MO. SERVICE INTERVAL
TEST & CHECKOUT SERVICES	POWER, DATA COMMUNICATIONS
PRESSURIZATION	ONE PRESS FOR FREE-FLYING & SORTIE RAMs
PROPULSION MODULES (SHUTTLE SUPPORTED)	MOUNTING (UP TO 4)
RENDEZVOUS & DOCKING	DOCKING ASSEMBLY WITH TELESCOPE MOUNT

72-1735

SORTIE RAM CONFIGURATION CHANGE

Three operational phases are involved in a sortie RAM configuration change: postflight, maintenance and refurbishment and payload integration. Postflight operations cover the period from orbiter landing to the beginning of RAM maintenance operations. After the orbiter lands, it is towed to the safing area, where the orbiter cooldown and safing operations are accomplished. RAM operations during this period include crew egress, removal of time-critical data, and safing RAM subsystems (shutting down the fuel cell, venting, etc.). Ground power, coolant supply monitor, and control via the orbiter payload umbilical panel are required throughout the cooldown period.

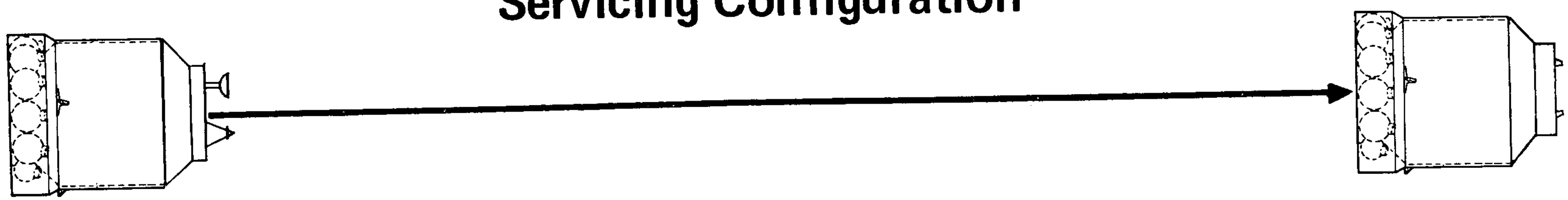
The orbiter is then towed to the shuttle maintenance facility. RAM is dormant for the remainder of postflight operations. RAM is disconnected and removed from the orbiter and placed on its holding/handling fixture, protective covers are installed and RAM is transported to the RAM maintenance facility.

RAM is connected to power and cooling ground interfaces and the final postflight operations completed, consisting primarily of non-support-critical data removal (magnetic tapes, plots, printouts, and logbooks, in this case). Maintenance operations begin with a review of mission housekeeping data and an inspection of the RAM and payload. The results of this review and inspection are used to augment a previously prepared maintenace plan.

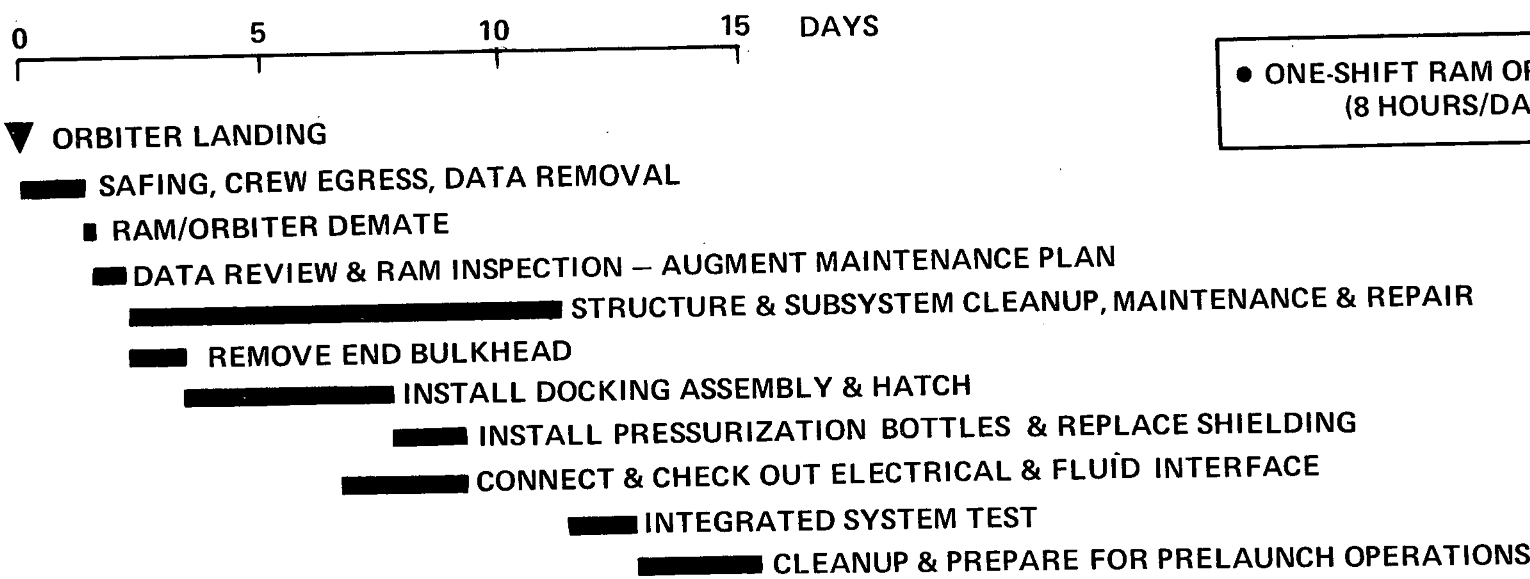
Routine cleanup and maintenance of subsystems require approximately nine eight-hour working days. In parallel with these operations, the sortie RAM and bulkhead is removed with the senosrs still in place; the docking mechanism is assembled, checked, and installed; three segments of micrometeoroid shielding are removed from the aft conical bulkhead; three GN_2 repressurization bottles are installed, connected, and checked; and micrometeoroid protection for the bottles is installed. If replacement of the RCS pods on the free-flying RAM is to be accomplished, mounting provisions for these pods are installed on the aft conical bulkhead.

While the external installations are taking place, the required internal electrical and fluid connections are verified. Payload internal equipment is not removed when the same payload will be reflown after the free-flying RAM servicing missions. A short integrated system test is accomplished next with orbiter and free flying RAM interfaces simulated. The sortie RAM is then cleaned up and prepared for prelaunch operations.

SORTIE RAM CONFIGURATION CHANGE
Communications/Navigation to Free-Flying RAM Servicing Configuration



POSTFLIGHT	MAINTENANCE & REFURBISHMENT	PAYLOAD INTEGRATION
• CREW EGRESS & REMOVE DATA • SAFE SUBSYSTEMS • DEMATE FROM ORBITER	• REMOVE PAYLOAD EQUIPMENT • PERFORM SCHEDULED & UNSCHEDULED MAINTENANCE	• INSTALL NEW EQUIPMENT • PERFORM INTEGRATED TEST



• ONE-SHIFT RAM OPERATIONS (8 HOURS/DAY)

72-1719

RAM subsystems provide payload support through all mission phases in varying degrees dependent upon the operations during each phase.

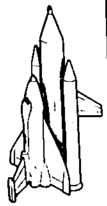
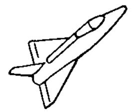
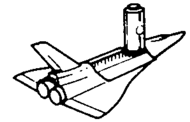
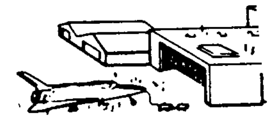
GROUND OPERATIONS PHASES – Payload integration and prelaunch/launch operations require horizontal and vertical access for such operations as servicing of expendables, equipment checkout and on-pad installation of time-critical items. Electrical power and thermal control subsystems require ground interface connections. Other RAM subsystems are activated to support ground testing and training.

Postflight operations require access for data/specimen removal and subsystem support with ground interfaces for crew support immediately following landing and during testing operations.

FLIGHT OPERATIONS PHASES – The electrical power system (EPS) is on, but providing power at a reduced level for payload support during boost and ascent (and entry and landing). On-orbit, the EPS provides maximum power during experiment periods. The environmental control/life support system provides full environmental control of the entire mission. A positive pressure (relative to outside RAM) must be maintained at all times for structural integrity. The thermal system operates continuously and adapts to environmental changes (by changing the heat removal method) when the orbiter cargo bay doors are opened or closed.

The control moment gyros used in the GN&C subsystem (for Astronomy payloads) are spun up through boost and remain on until the on-orbit experiment period is completed. Controls and displays support manned operations in RAM. The communication/data management system operates continuously during the flight portion of the mission; payload data is stored on magnetic tape. Communication links are supplied through the orbiter. The structures and mechanical subsystem is compatible with boost and entry flight loads and adaptable to manipulator and pivoted methods of on-orbit RAM deployment (and retraction). The crew and habitability subsystem provides for two payload crewmen in a sortie RAM and for up to four payload crewmen in an RSM.

SORTIE MISSION SUBSYSTEM STATUS

SUBSYSTEM \ MISSION PHASE	PAYLOAD INTEGR. & PRE-LAUNCH/ LAUNCH 	ASCENT 	ON-ORBIT 	ENTRY 	POSTFLIGHT 
STRUCTURE	SEA LEVEL OPS.	BAY OPS.	SPACE OPS.	BAY OPS.	SEA LEVEL OPS.
THERMAL CONTROL	GROUND I/F	HEAT STORAGE & SUBLIMATOR	SPACE RADIATION	HEAT STORAGE & SUBLIMATOR	GROUND I/F
EC/LS	CREW SUPT.	CREW SUPT.	CREW SUPT.	CREW SUPT.	CREW SUPT.
ELECTRICAL POWER	GROUND I/F	REDUCED LOAD	FULL LOAD	REDUCED LOAD	GROUND I/F
COMM/DATA	TEST & TRAINING OPS.	REDUCED DATA	FULL DATA	REDUCED DATA	DORMANT
CONTROLS & DISPLAYS	TEST & TRAINING OPS.	CAUTION & WARNING	STATUS & PERFORMANCE	CAUTION & WARNING	TEST OPS.
ONBOARD CHECKOUT	TEST & TRAINING OPS.	CAUTION & WARNING	STATUS & PERFORMANCE	CAUTION & WARNING	TEST OPS.
HABITABILITY (RSM)	VERT/HORIZ ACCESS & EGRESS	SEATS	RESTRAINTS	SEATS	EGRESS

72-1712

RAM SORTIE MISSION CAPABILITIES AND CHARACTERISTICS

The family of RAM elements provides flexible payload carriers for sortie missions. They are readily adaptable to a wide range of payload requirements. Basic subsystem capabilities are sufficient for most payloads; subsystem add-ons are available to increase particular subsystem capabilities as the need arises. Low-g space environments are possible through shuttle/RAM operational techniques; contamination and radiation countermeasures are provided by RAM. Orbits with inclinations up to polar and sun-synchronous and altitudes up to 400 n.mi. are within sortie mission capabilities.

User participation is enhanced through a simplified payload interface which provides: (1) resources (power, date handling, etc.) to the payload through a standard interface; (2) provisions for equipment mounting; (3) cold plate and air interfaces for thermal control; and (4) a variety of standardized experiment integration equipment items for adapting payloads to the RAM interface. Useful scientific results can be obtained with two payload crewmen; however, with the maximum payload crew of six, mission specialists who are highly skilled in space operations will be available to assist payload specialists during on-orbit operations. This approach also permits payload specialists to be recruited from the scientific community for particular space experiments and to function on-orbit without extended periods of training in RAM/shuttle interfaces and space operational techniques.

RAM elements are recoverable and reusable, as payload carriers for the same or new payloads. The RSM is capable of providing payload resources to different payload modules on sequential missions by virtue of a rapid ground turnaround cycle. The family of pressurized RAM modules logically evolves from the sortie RAM, used during early missions, to the RSM or payload module configurations as payload demands increase during later missions. Modular additions and/or deletions permit convenient reconfiguration of the sortie RAM to the RSM, sortie mission payload module, or station-attached payload module. The approach of evolving the family of pressurized RAMs from a single element permits highly flexible support with reduced overall funding.

An onboard checkout system integral to RAM frees the payload crew from routine status determinations while on-orbit and speeds ground turnaround through automatic subsystem checkout. Sufficient redundancy is built into RAM to protect personnel while on-orbit and to permit maintenance-free flight operations with all maintenance accomplished on the ground during normal RAM element turnaround procedures. Provisions are incorporated in RAM for subsystem add-ons to extend mission duration beyond the nominal seven days, should this option become desirable.

RAM SORTIE MISSION
Capabilities & Characteristics

- ADAPTABLE TO WIDE RANGE OF PAYLOADS
  - RESOURCES
  - ENVIRONMENT
  - ORBITS & VIEWING
- SIMPLIFIED PAYLOAD INTERFACE
- USEFUL SCIENTIFIC DATA WITH 2 TO 6 PAYLOAD CREWMEN
- MULTIPLE USE/REUSE
- LOGICAL ELEMENT EVOLUTION
- CONVENIENT RECONFIGURATION
- SELF-CHECKOUT
- MAINTENANCE ON GROUND
- MISSION EXTENSION BEYOND 7 DAYS WITH ADD-ONS

72-1707

FREE-FLYING RAM – DESIGN & OPERATIONS

G. Karel

- REQUIREMENTS
- SUBSYSTEMS
- CONFIGURATIONS
- INTERFACES
- CAPABILITY

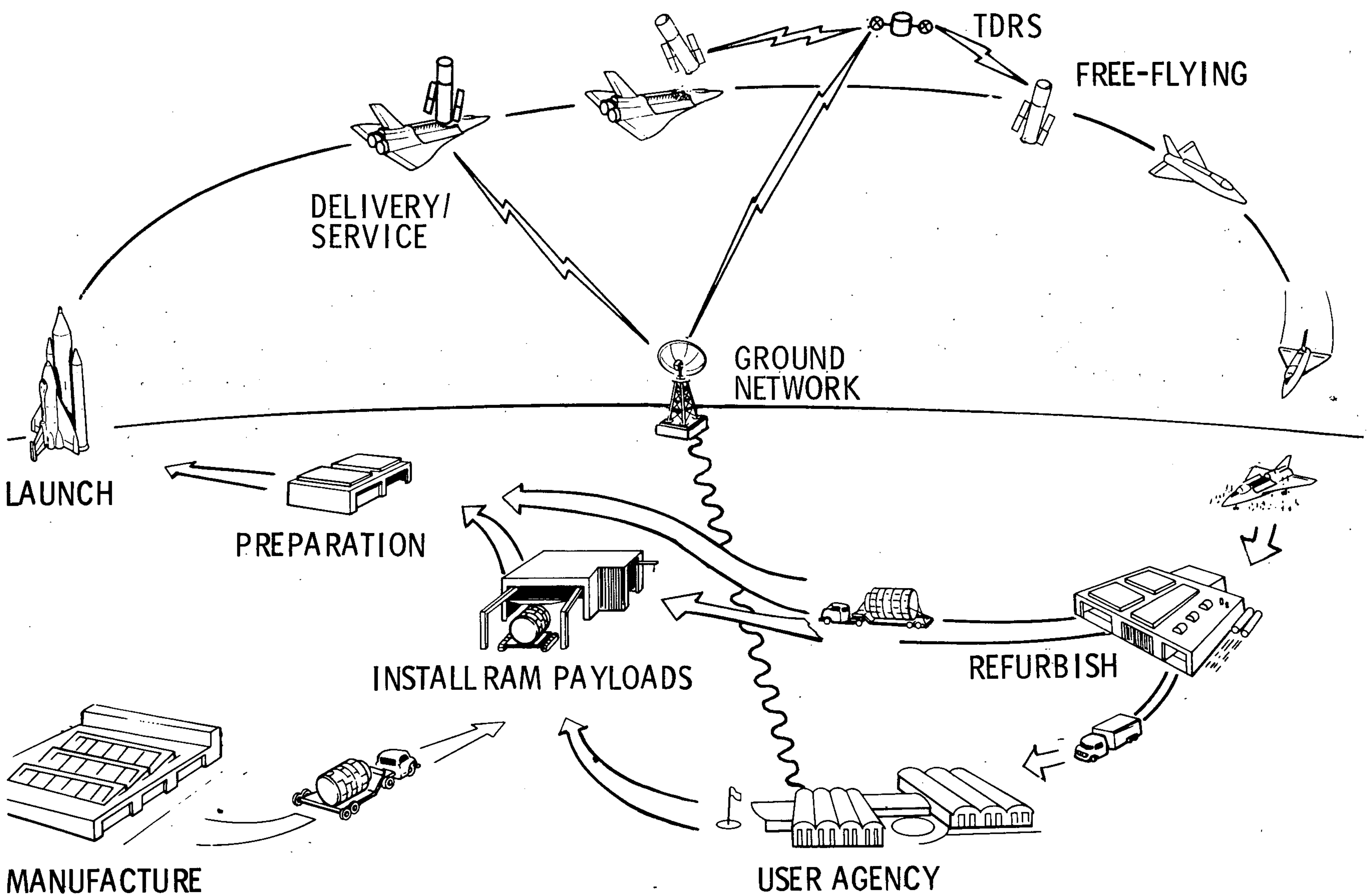
72-1807

FREE-FLYING RAM MISSION

The Space Shuttle delivers free-flying RAMs to the required mission orbit. Once in orbit, RAM is deployed and an initial checkout of RAM systems is made before it is released from the shuttle. The checkout is primarily automatic, but participation by the two RAM payload specialists is required to to break certain interface connectors between the shuttle and RAM to release the RAM. Upon release, final system checkout is conducted by the ground crew, using the TDRS communication link. Shuttle then returns to base.

The free-flying RAM mission duration is five years, with servicing at six-month intervals either by shuttle visits to RAM or RAM visits to the Space Station. Due to the five-year mission duration, the dominant ground activity will be at the station monitoring the free-flying RAM and receiving the considerable quantities of data being generated.

RAM FREE-FLYING MISSION



72-1770

RAM FREE-FLYING MISSION PAYLOADS

The representative payloads selected to provide design and operational requirements for free-flying RAM are the four man-tended observatories shown on the facing chart. The source of definitions of three of these observatories is the Blue Book, with the LST Advanced Stellar being an updated definition from that contained in the Blue Book, based on studies conducted by MSFC

The Advanced Stellar X-Ray Observatory consists of focusing telescopes and focal plane sensors, as well as detectors and instruments mounted at the front of the telescope.

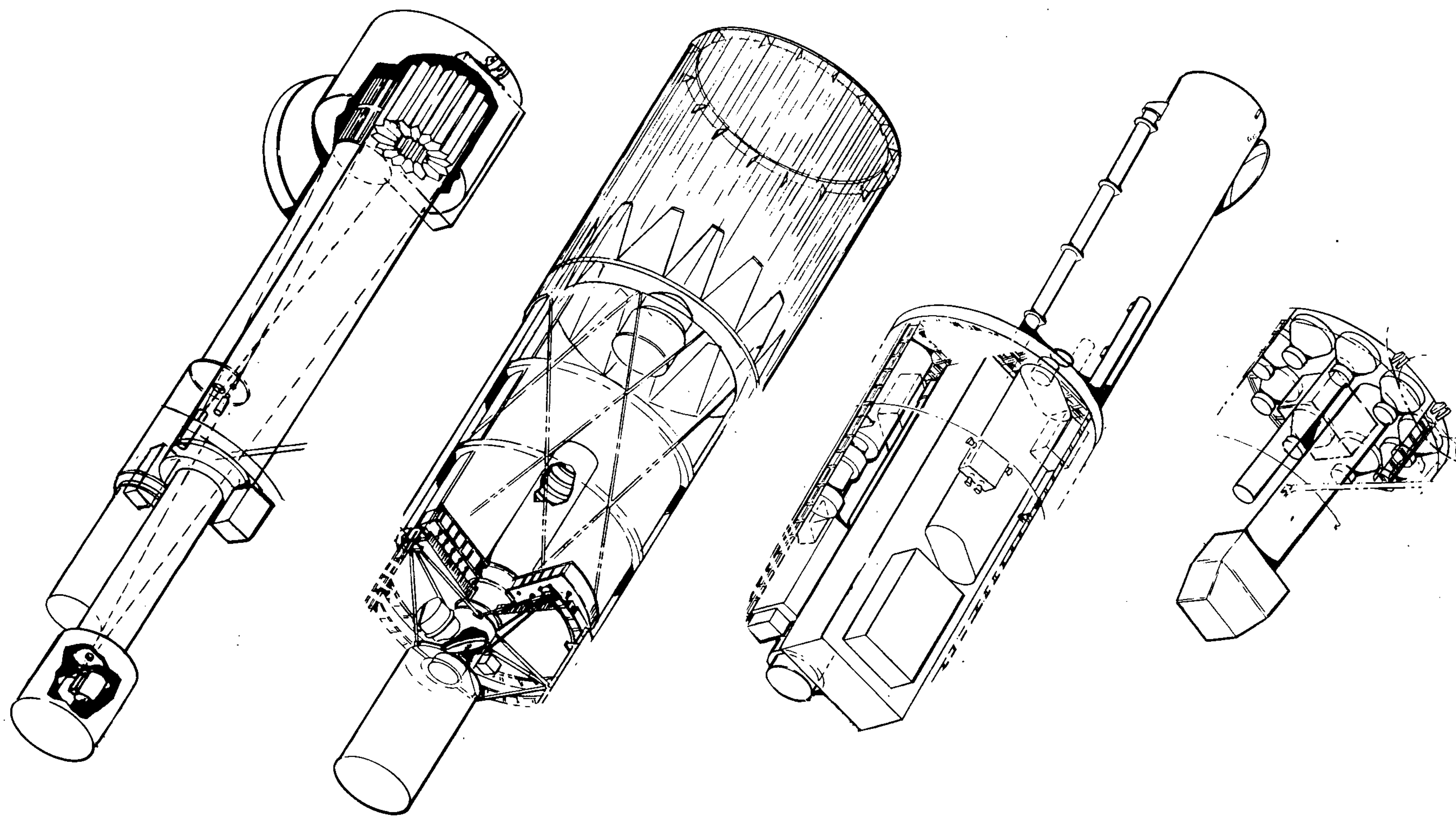
The LST Advanced Stellar Observatory is a nominal three-meter optical telescope with sensors mounted in a structure below the primary mirror.

Advanced Solar Observatory contains a 1.5-meter photoheliograph as the principal instrument, accompanied by coronagraphs and smaller x-ray and XUV telescopes.

The High-Energy Observatory would house a selected set of gamma- and x-ray detectors and telescopes from the wide range of instruments available.

This combined set of four instrument groupings provides a wide range of operational, interface, and design requirements to drive the design of the free-flying RAM.

RAM FREE-FLYING MISSION PAYLOADS



ADVANCED STELLAR X-RAY ASTRONOMY

LST ADVANCED STELLAR ASTRONOMY

ADVANCED SOLAR ASTRONOMY

HIGH-ENERGY STELLAR ASTRONOMY

72-1814

POINTING – The basic stabilization and pointing requirement on the free-flying RAM is 1 arc-sec. Some payloads, such as Large Space Telescope and Solar Astronomy contain payload-provided guidestar-tracker sensors capable of detecting positional errors with respect to reference stars to less than 0.1 arc-sec. and angular perturbations to less than 0.005 arc-sec. and providing error signals to point and to stabilize the optical line of sight. The free-flying RAM stabilization and control subsystem provides optional reaction wheel add-ons to obtain stabilization better than that provided by the basic RAM subsystem. Where applicable, the portion of the requirement satisfied by the payload instrument or RAM subsystem add-on is indicated on the facing chart.

DATA RATES – For x-ray and high-energy payloads, the peak data rates shown occur only for about 51 seconds for one orbit per day and are used to monitor rapidly varying x-ray sources such as pulsars. Average real-time data rate for monitoring the field of view for aspect sensing, location of sources with respect to reference stars, as well as internal jitter stabilization is about 7.3 x 10^6 bps. If onboard reduction of data is accomplished within the experiments, the reduced data delivered to RAM could range from 1.5 x 10^4 to 3.7 x 10^4 bps.

For the Large Space Telescope the high-rate data is accumulated and integrated by the payload-provided image enhancement processor. The output to RAM is 5 x 10^6 bps.

For Solar Astronomy, the peak data rate comes from multisensor multispectral operation of 14 solar sensors at the same time. Options exist in the RAM to record 14 channels of data at the peak combined rate of 1.24 x 10^9 bps, or at peaks of about 1.59 x 10^8 bps with data compaction provided by the payload. Average output from the RAM data recorders will be at less than about 1 x 10^7 bps. The high data rates exist for a few seconds during testing and for two 20-second periods per orbit, when solar phenomena requiring maximum correlation of data are observed. The solar instruments also may be used in sequential fashion with a lesser number of sensors operating at the same time. The RAM data subsystem can accept a variable range of input data rates.

VOLUME – Volume shown for each representative payload is the equipment volume which is located in the pressurizable RAM compartment. Access volume is not included.

PAYLOAD ACCOMMODATION REQUIREMENTS

REQUIREMENT		X-RAY	STELLAR (LARGE SPACE TELESCOPE)	SOLAR	HIGH ENERGY STELLAR
POINTING STABILITY (ARC-SEC./OBS.)	RAM INSTRUMENT	1	1 0.005 *	1 0.017 *	1
POINTING ACCURACY (ARC-SEC.)		1	1	1	2
AVG. POWER-ON (WATTS)		1,240	1,000	2180	750
DATA-PEAK DIGITAL (BITS/SEC.)		1.2×10^8	5×10^6	1.24×10^9	1.2×10^8
VOLUME-INTERNAL (CU. FT.)		137	654	1,513	122

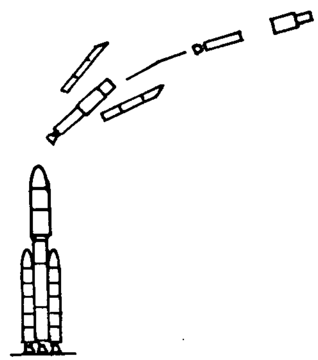
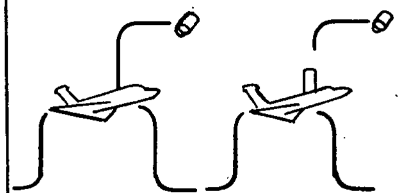
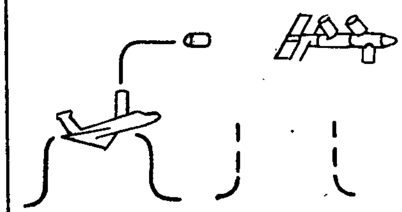
*Provided through experiment integral vernier or body point with reaction wheels.

72-1775

MISSION/OPERATIONS REQUIREMENTS
Free-Flying RAM

Titan and shuttle-launched free-flying RAM mission/operations requirements are shown in this chart. For the shuttle-launched case, shuttle-supported and station-supported requirements are differentiated. Other characteristics reflect both payload requirements and launch vehicle capability;. The Titan IIID-launched free-flying RAM is the Large Space Telescope. It is inserted into an elliptic orbit and must supply its own orbit circularization capability. Orbit maintenance (as required) must be provided by the LST (during the two years before the initial shuttle service visit) and by station-supported free-flying RAMs. Active rendezvous and docking delta V capability is required only by the station-supported free-flying RAMs. Attitude stabilization during shuttle docking (for on-orbit service) is required. The LST communication link is direct to MSFC. Shuttle-supported (shuttle-launched) free-flying RAM communication links are direct to TDRS while the station-supported link is through the station to TDRS/MSFN. The LST and shuttle-supported free-flying RAMs are serviced on-orbit by the shuttle (with sortie RAM for support) at six-month intervals (nominal), or as required. The station-supported free-flying RAM returns to the station periodically for service. Both the Titan and shuttle-launched free-flying RAMs are designed for five-year mission durations. Contamination isolation impacts free-flying RAM operations requirements, implementation methods, and subsystem selection.

MISSION/OPERATIONS REQUIREMENTS
Free-Flying RAM

REQUIREMENT	TITAN LAUNCHED	SHUTTLE LAUNCHED	
		 SHUTTLE SUPPORT	 STATION SUPPORT
ORBIT ALT. (N. MI.)	300 TO 400	300 TO 400	240 TO 270
ORBIT INCL. (DEG.)	28.5 TO 40	28.5 TO 55	55
ORBIT INSERTION	RAM CIRCULARIZATION	SHUTTLE	SHUTTLE
ORBIT MAINTENANCE	RAM	SHUTTLE	RAM
RENDEZVOUS & DOCKING	ATTITUDE	ATTITUDE	ATTITUDE & ΔV
COMMUNICATIONS	MSFN	TDRS	STATION
ON-ORBIT SERVICING	SHUTTLE/RAM	SHUTTLE/RAM	STATION
MISSION DURATION (YR.)	5	5	5
CONTAMINATION ISOLATION	YES	YES	YES

72-1774

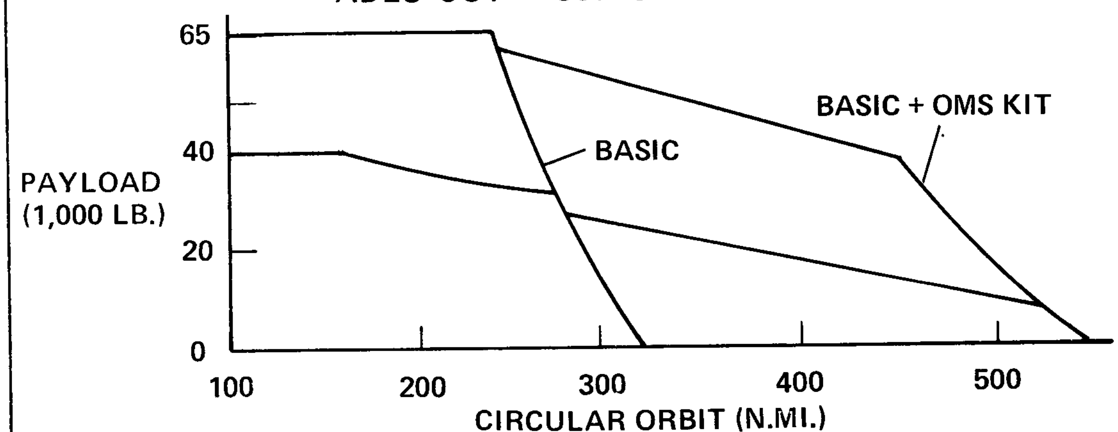
REFERENCE SHUTTLE PERFORMANCE

Several significant performance interface characteristics of RAM reference Space Shuttle are shown. The payload to orbit altitude capability shown assumed that the Shuttle's main propulsion subsystem injected the orbiter vehicle into a 50 x 100-n.mi. orbit and the OMS performed the circularization at 100 n.mi. followed by a coplanar orbital transfer to a higher altitude and the deorbit maneuver. The two limiting payload to orbit curves shown in the chart represent the capability of the basic OMS which is an integral part of orbiter vehicle, and the OMS kit which can be added to orbiter vehicle to increase the orbital altitude capability. Both the basic OMS and the OMS kit have 1,000-fps velocity increment capability, but the OMS kit volume and weight are chargeable to payload. The two Shuttle Level 1 guidelines represented in the chart are;

1. Shuttle will be launched due east and requires a payload of 65,000 lb. with the orbiter vehicle airbreathing engines removed. For this mission orbiter vehicle on-orbit translational velocity requirements are 1,000 fps from the orbital maneuver subsystem (OMS) and 120 fps from the RCS.
2. Shuttle will be launched into a polar orbit and requires a payload capability of 40,000 lb., with the orbiter vehicle airbreathing engines removed. For this mission orbiter vehicle on-orbit translational velocity requirements are 650 fps from the orbital maneuver subsystem and 120 fps from the RCS.

Total allowable launch weight of RAMs on a single shuttle is not to exceed 80% of shuttle payload to orbit performance capability, as represented by the payload/orbital altitude curve presented on the chart.

REFERENCE SHUTTLE
Performance

CHARACTERISTICS	INTERFACE
PERFORMANCE TO ORBIT PAYLOAD/ORBIT CAPABILITY BASIC OMS OF 1,000 FPS OMS KIT OF 1,000 FPS	ABES OUT — 80% CAPABILITY TO ORBIT 
LANDING WEIGHT	40,000 LB. FULL SAFETY FACTOR
POINTING/STABILITY	±0.5°/±0.03 DEG./SEC., ALL-AXIS
ELECTRICAL POWER	28 VDC/1,000 W AVG./ 50 KWH TOTAL ENERGY
COMMUNICATION	VOICE: S-BAND/MSFN & VHF/TDRS DATA: S-BAND/MSFN: 1 MBPS VHF / TDRS; 10 KBPS GRD TRACKING: S-BAND/MSFN RENDEZVOUS RANGING: VHF
CONTAMINATION SOURCES	ACPS, CABIN LEAKAGE & OUTGASSING

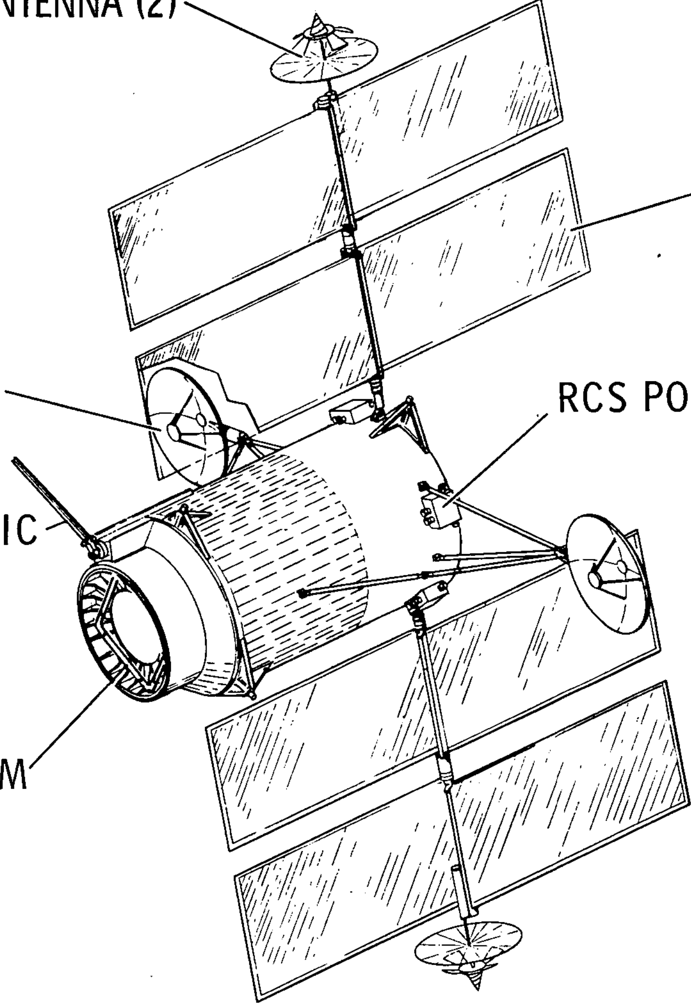
72-1679

FREE-FLYING RAM
Shuttle-Launched

A general arrangement of the free flying RAM without experiment payload is shown. It has an open-ended structure of 12-foot nominal outside diameter and 22.58 feet in length. At one end is a standard 102-inch diameter dock and 60-inch diameter contamination shield. The open end is closed by an experiment-peculiar pressure bulkhead structure, which varies with the different experiment payloads accommodated. Four roll-out solar cell arrays form a dragonfly configuration for three of the four payloads accommodated. The other payload requires only two arrays. The propulsion/RCS units are located adjacent to the array and antenna mounts to avoid direct plume impingement on these mounts, the arrays, or the shuttle attachment fittings. Length of the antenna mount is derived from the requirement to provide complete communication coverage with solar cell arrays deployed.

The three-meter LST payload is accommodated by the basic RAM free-flyer structure. Since the LST must be compatible with launch by either a shuttle or Titan III, the external appendages are constrained to fit within the Viking shroud. The propulsion/RCS units are of a lower profile with the propellant tanks located around the docking tunnel. In addition, two 600-lbf thrusters and added propellant are required for orbit circularization, if launched by the Titan III.

FREE-FLYING RAM
Shuttle-Launched



FOR TITAN LAUNCH

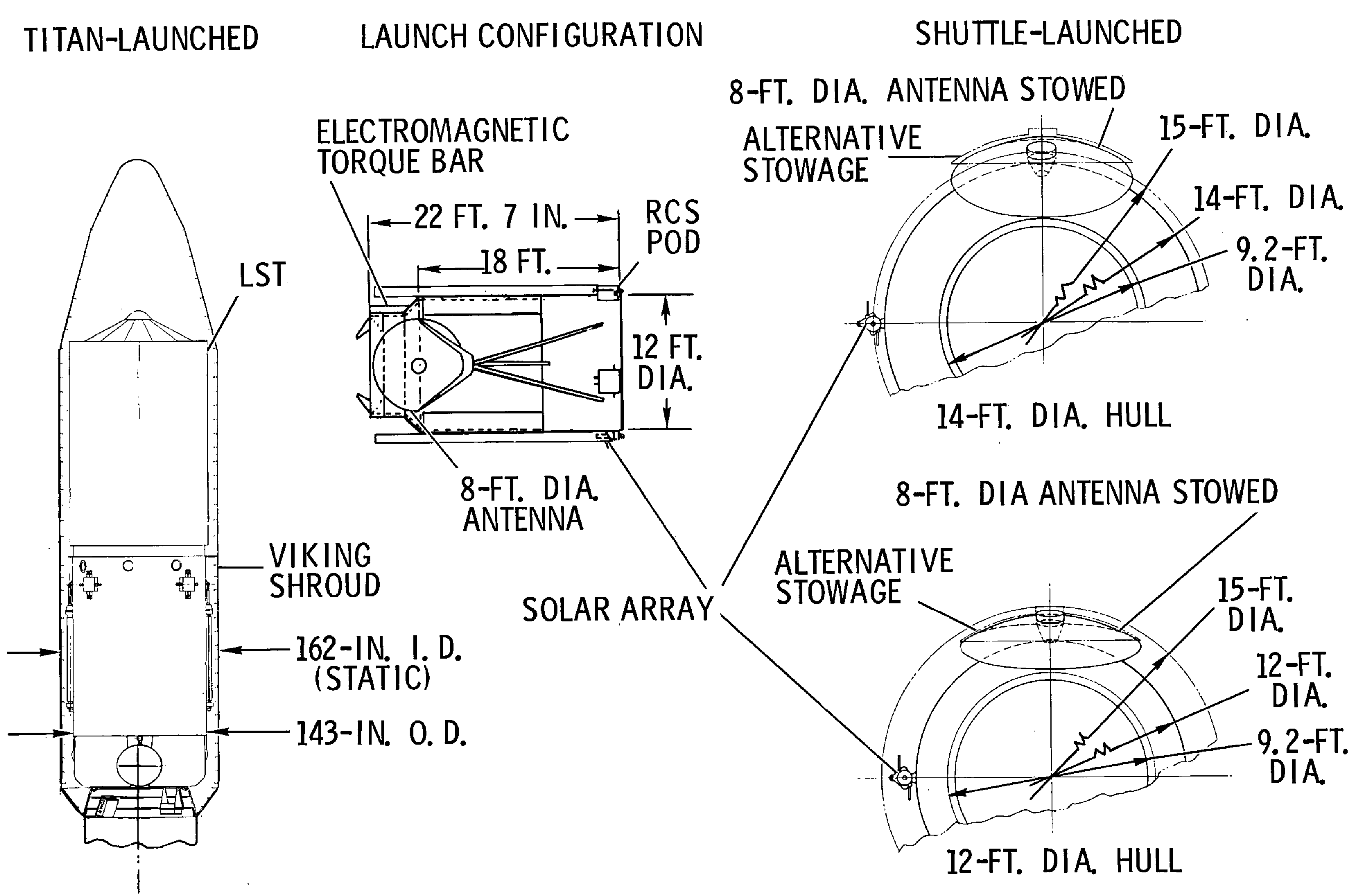
1. PARABOLIC ANTENNA DELETED
2. TWO 600-LB. THRUST ORBIT CIRCULARIZATION MOTORS & RANKAGE ADDED.
3. USE SINGLE WING SOLAR ARRAYS
4. CHANGE TO CENTRALIZED RCS TANKAGE.

72-1804

FREE-FLYING RAM DIAMETER CONSIDERATIONS

Some of the considerations involved in the derivation of the fre-flying RAM diameter are shown. The Large Space Telescope (LST), if Titan launched, is limited to an outside diameter of 143 inches to fit within the Viking shroud. The possibility of using a 14-foot diameter, which is common with the pressurized RAMs, was investigated. It was concluded that the 14-foot diameter results in untenable design compromises to the external susbystems because of the limiting shuttle cargo bay envelope of 15-foot diameter. This leaves only six inches clearance outside of the radiator/meteoroid shielding. The solar cell arrays, RCS and eight- foot diameter antennas present clearance problems. For example, the retracted solar cell array cylinders require two troughs in the primary pressure wall over nearly the entire length and considerably reduce the radiator area. An alternative would be to telescope the solar array mount to stow the arrays at the viewing end of the free-flyer (aft end of cargo bay). This intrudes into the area occupied by the OMS.

FREE-FLYING RAM DIAMETER CONSIDERATIONS



72-1699

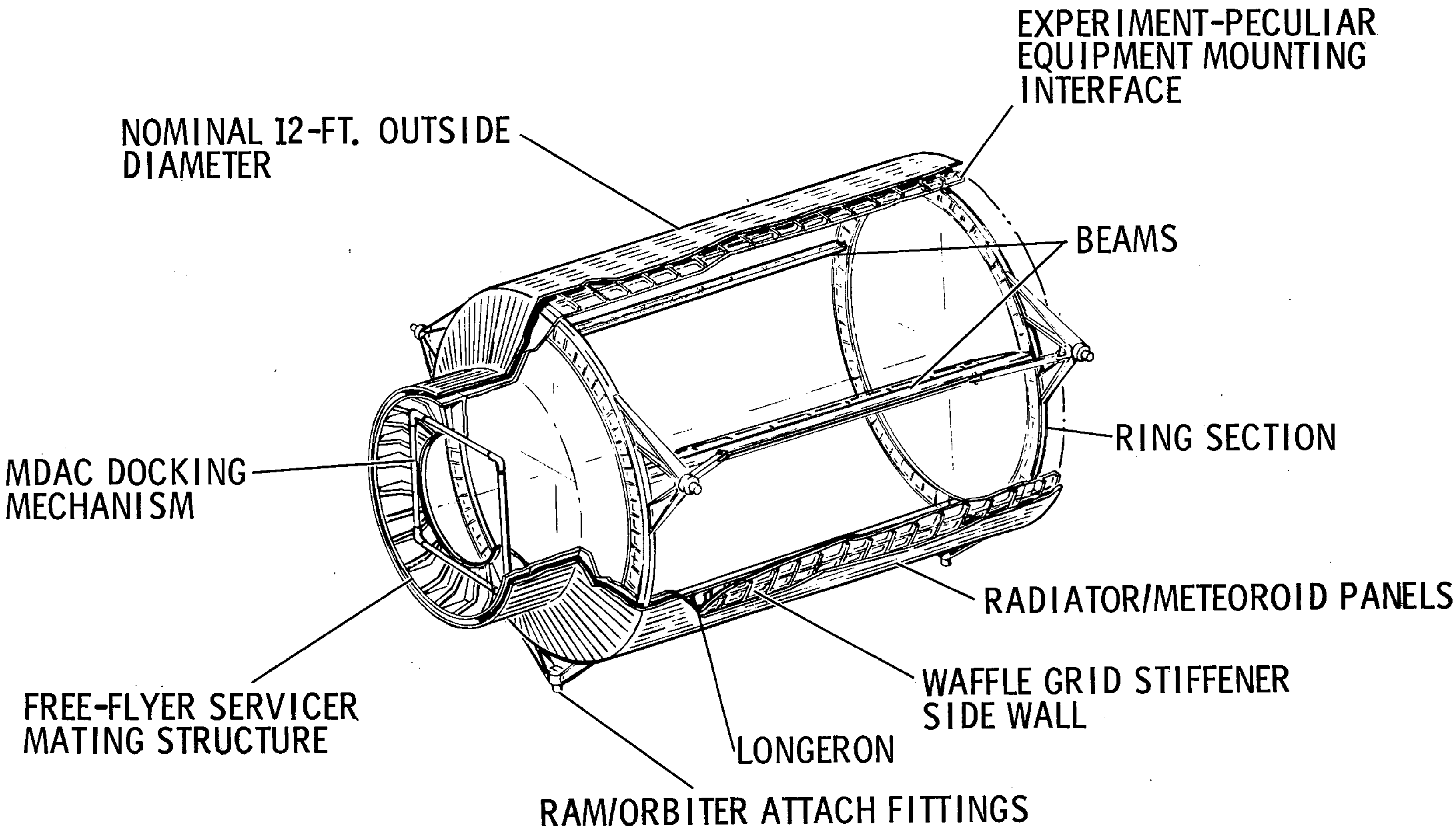
FREE-FLYING RAM MODULE STRUCTURE

The free-flying RAM structure provides support for astronomy experiments and containment of a livable atmosphere so that experiment equipment may be maintained in a shirtsleeve environment. The structure must hold internal pressure and react external forces due to boost and maneuvering loads imposed by the orbiter and by docking procedures.

The structure is made up of the pressure shell, which consists of cylindrical walls, bulkhead and mating adapter. It also consists of the environmental protection system and secondary structure that supports internal and external equipment.

The structure is basically a cylindrical shell with conical bulkheads. It has a maximum internal diameter of 135 inches and a diameter over the cylindrical section of 12 feet. Overall length of the structure is approximately 22.58 feet. The total internal volume of the pressurized module structure is 2,125 cubic feet.

FREE-FLYING RAM STRUCTURE



72-1803

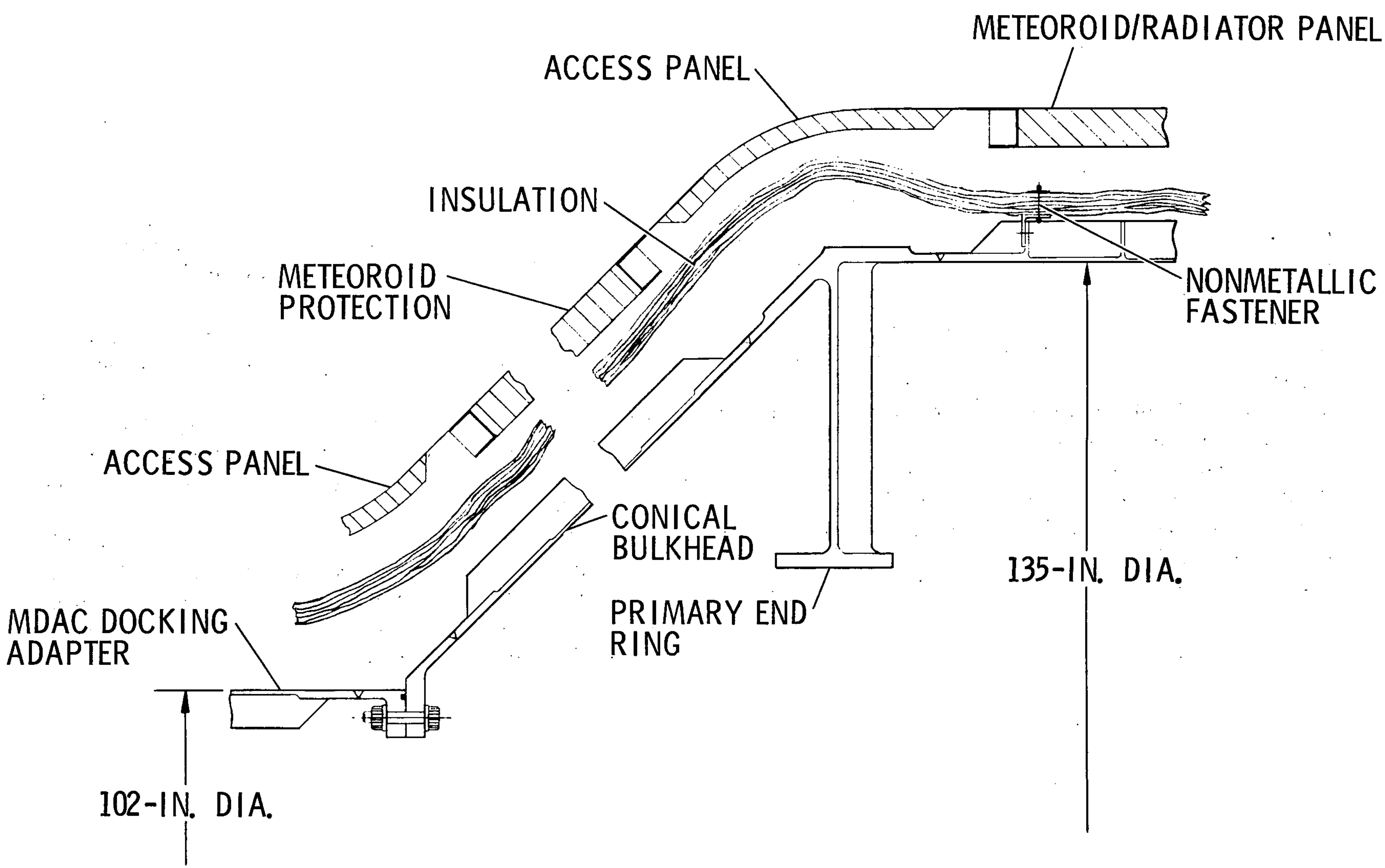
FREE-FLYING RAM STRUCTURE
Details

The five free-flying RAMs use a common structure for the basic pressurized module. The module is a 135-inch diameter cylinder, 216 inehes long. Attached to the forward end of this cylinder is a 45-deg. conical bulkhead a 23.5-inch long, 102-inch diameter adapter section, and the MDAC docking adapter. The experiment-peculiar structure is bolted to the aft end of the cylinder at the 135-inch diameter. The five orbiter attachment fitting assemblies are bolted to the cylindrical section as are the RCS motor packages, the antennas and the solar arrays. The docking adapter used on the free-flying RAMs is the design developed by MDAC and used on all RAM elements. The 102-inch diameter adapter is 23.5 inches long; otherwise, it is identical to that used on the sortie RAM.

The cylindrical sidewall consists of three panels 209 inches long rolled to the 135-inch inside diameter and a ring section 7 inches long. It has two primary end rings each 8 inches deep with I cross-sections. The 7-inch long ring is used to attach the aft primary ring and the orbiter fittings and acts as the splice joint to the experiment peculiar structure. It is welded to the three cylindrical panel sections. Two longitudinal I-beams are welded into the cylindrical section at a location approximately 15 deg. above the horizontal centerline. The beam at the -Y location, the left side looking forward, is 12 inches deep; the other beam is 3 inches deep. A longeron is welded into the cylinder at the -Z bottom centerline. The three cylindrical panels span between the beams and to the longeron on the bottom centerline. The cylindrical panels are made with integrally machined grid stiffeners. This waffle structure is identical to that used on sortie RAMs and payload modules.

The conical bulkhead makes the transition between the 135-inch diameter cylindrical sidewall and the MDAC docking adapter. The bulkhead is in the form of a 45-deg. cone similar to that used on the sortie RAMs. The RAM/orbiter attachment fitting concept used on the free-flying RAM is the five-point reaction statically determinant system used on the sortie RAMs. The differences lie only in the physical size of the fittings and diameter of the cylindrical sidewall. The environmental protection system is identical in all respects to that used on the sortie RAMs, except for the dimensions of the panels.

FREE-FLYING RAM STRUCTURE
Details



72-1777

The structure of the free-flying RAM is identical to sortie RAMs except for the nominal 12-foot diameter. The pressure wall thickness was selected by both manufacturing minimums and by the optimum waffle structure configuration. The meteoroid requirements of these modules are more stringent than the sortie RAMs due to the longer mission time. The requirements tend to drive the design point from the meteoroid protection criteria nearer to the manufacturing minimums than in the other modules.

For commonality all meteoroid bumpers have been standardized; the primary bumper is 0.016 inch and the secondary bumper is 0.010 inch thick. These thicknesses were determined by the probability of no prenetration requirements and by the five-year free-flying RAM mission.

The five-point RAM/orbiter attachment concept was derived from the requirement of static determinacy. This system is identical to the sortie RAM except for dimensional differences. One implication of this requirement is that the longitudinal loads are reacted at one location, resulting in a large couple or moment induced into the module sidewall. An internal beam structure was selected for this task as it yields the lowest weight system, is the best from manufacturing considerations and – most important – neither cuts through the radiator system nor induces thermal shorts into the basic module structure.

Data developed in this study shows that 2219-T851 aluminum alloy is the best material for components of the pressurized RAM module. It was selected on the basis of its excellent corrosion resistance, fracture toughness, weldability, and machinability.

STRUCTURAL SUBSYSTEM
Free-Flying RAM

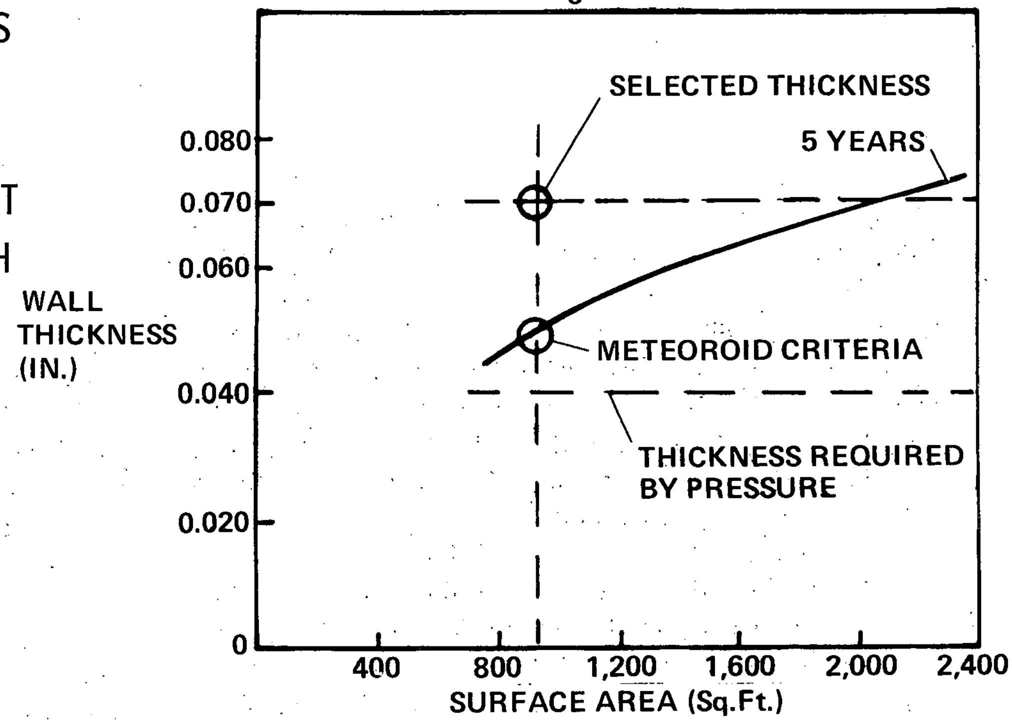
BASIC SUBSYSTEM PARAMETERS

- 0.070-IN. PRESSURE SHELL THICKNESS
- 0.016-IN. METEOROID BUMPER
- 0.010-IN. SECONDARY BUMPER
- FIVE-POINT RAM/ORBITER ATTACHMENT
- INTERNAL BEAMS FOR ORBITER ATTACH FITTINGS
- 2219 ALUMINUM ALLOY

RATIONALE FOR SELECTION

- MINIMUM WEIGHT
- $P_0 = 0.995$ FOR 5.0 YEARS
- PROTECTION OF INSULATION
- BY STATIC DETERMINACY
- TO REDUCE HEAT SHORTS & NOT REDUCE RADIATOR AREA
- WELDABILITY, FRACTURE TOUGHNESS & CORROSION RESISTANCE

METEOROID PROTECTION REQUIREMENTS
$P_o = 0.995$



SIGNIFICANT TRADE STUDY RESULTS

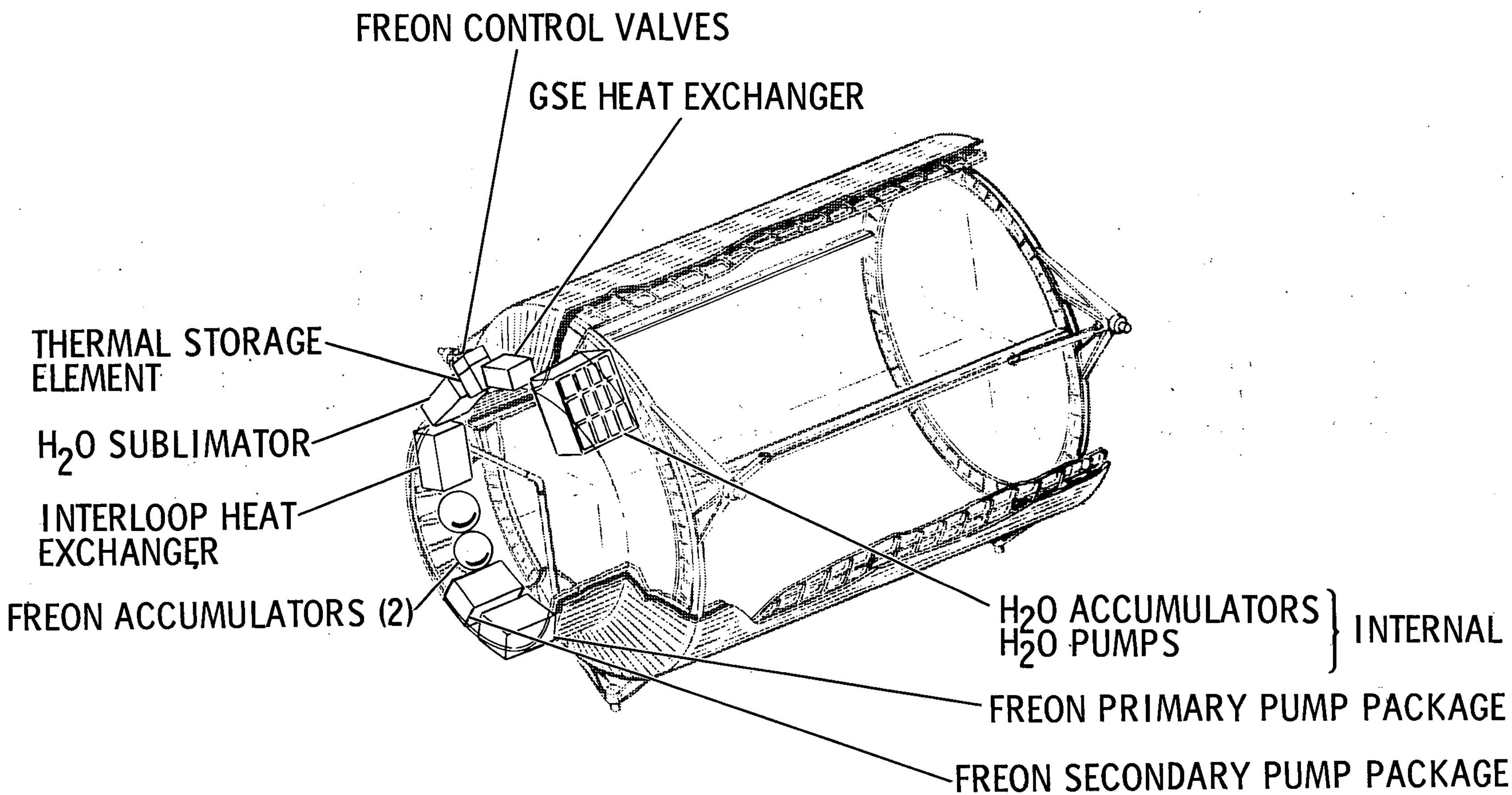
- SIDEWALL STIFFENING REQUIREMENTS MINIMAL WITH 0.070-IN. SKIN THICKNESS
- WAFFLE GRID SIDEWALL - LIGHTEST
- LONG LIFE CONSIDERATIONS - NOT CRITICAL
- MAXIMUM Nx = 552 LB./IN.

72-1805

THERMAL CONTROL SYSTEM
Free-Flying RAM

The heat transport system is similar to the Sortie RAM, but without EC/LS and fuel cell heat exchangers. However, the free-flying RAM thermal control system does have radiator bypass valves. Radiator area is 375 sq. ft. Warm Freon lines are routed near the RCS propellant tanks and lines to prevent freezing. Internal TCS equipment is mounted in a rack between two of the CMGs. This includes H_2O pumps and accumulators except on the Large Space Telescope (LST) which does not have an internal water loop. The remaining thermal control equipment is mounted around the exterior of the 102-inch diameter tunnel at the docking end of the RAM. Any unique thermal control requirements, such as precise temperature control over large surfaces or cryogenics for sensors, are considered to be experiment-peculiar and provided as a part of the payload.

THERMAL CONTROL SYSTEM
Free-Flying RAM



72-1793

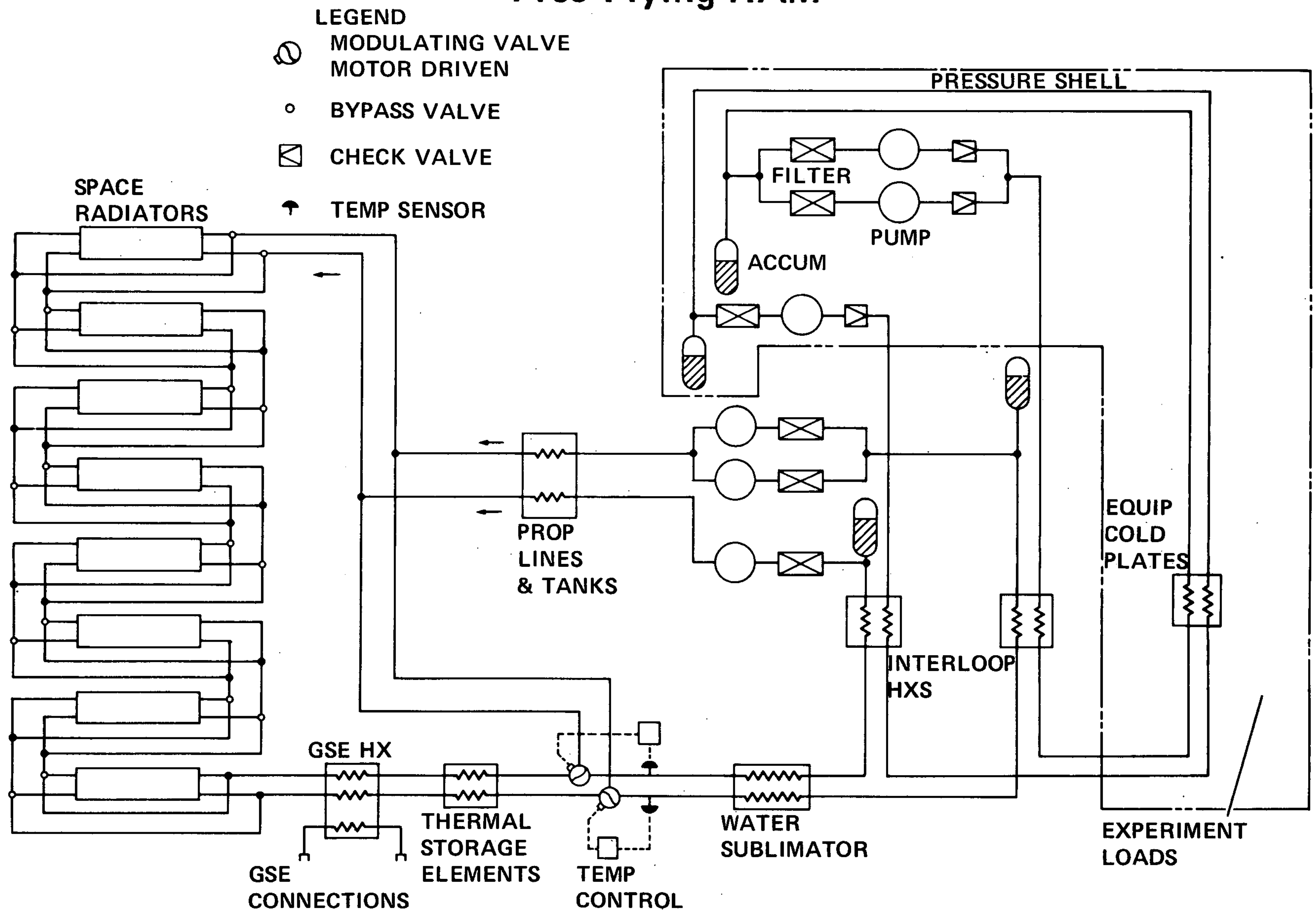
THERMAL CONTROL SUBSYSTEM SCHEMATIC

Free-Flying RAM

The free-flying RAM thermal control subsystem consists of two fluid systems. Water is used internally because of commonality with the thermal control system used in the other RAM elements and excellent heat transfer capability. The water transfers heat from all the interior heat sources to an external Freon 21 system across an interloop heat exchanger. This heat is transferred to the radiator panels and rejected to space. The Freon supply temperature to the intercooler is maintained at a nominal value of 35F for battery cooling by a radiator bypass control. Thermal damping during periods of rapid transients or peaking loads is provided by the thermal storage element. This element is sized for the re-entry condition when neither the radiators nor the sublimator can be used. The sublimator is used for on-orbit cooling during periods when the cargo bay doors are closed. Redundancy is provided in both loops, by using two independent circuits for each loop.

The subsystem interfaces with a ground coolant supply through the GSE heat exchanger. This supplies cooling during prelaunch and postlanding operational phases.

THERMAL CONTROL SUBSYSTEM SCHEMATIC
Free-Flying RAM



72-1769

THERMAL CONTROL SUBSYSTEM
Free-Flying RAM

The basic subsystem parameters shown were based on plus-three-sigma heating for the space radiators and shuttle equipment performance for the sublimator. The thermal storage element was sized for 1.5 hours of operation, which includes a 30-minute postlanding period to GSE hook-up. A phase change material with heat of fusion of 90 Btu/lb. was assumed. The radiator area is that available using the sidewall area.

The methods of heat rejection and thermal control were compared and selection based on weight, cost, and system complexity. The radiators were selected because the weight of expendables for the loads anticipated over a long-term mission would be prohibitive. The sublimator was selected for use on-orbit when the cargo bay doors are closed. The selected component is common with shuttle equipment. The thermal storage element provides passive control when neither the sublimator nor radiators are usable. Since the functioning of the unit is automatic, with no moving parts, minimum system complexity results.

The radiator coating selection was based primarily on a comparison of the Teflon/Ag/Inconel second- surface mirrors with Z-93 white paint. Radiator panel bypass valves will be required for either coating because of eventual coating degradation. The second-surface mirror was chosen to be common with that of the other RAM elements.

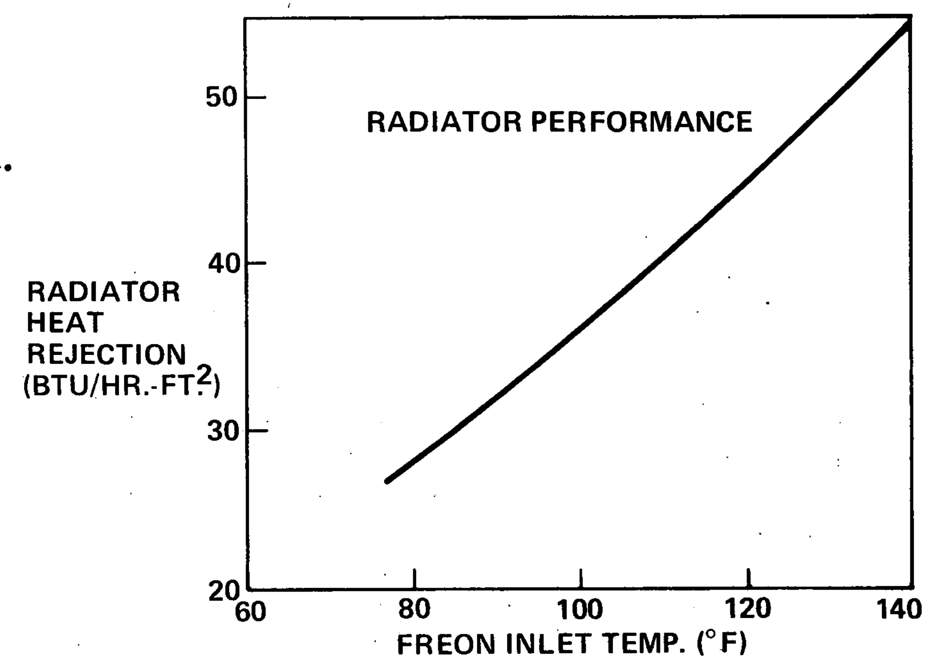
THERMAL CONTROL SUBSYSTEM
Free-Flying RAM

BASIC SUBSYSTEM PARAMETERS

- FREON TEMPERATURE CONTROLLED TO 35°F
- RADIATOR HEAT REJECTION: 10,500 BTU/HR.
- SUBLIMATOR HEAT REJECTION: 74,000 BTU/HR.
- THERMAL STORAGE: 13,900 BTU
- RADIATOR AREA: 375 FT^2

SELECTION RATIONALE

- BATTERY COOLANT REQUIREMENT
- RADIATORS - LOWEST ON-ORBIT WEIGHT
- THERMAL STORAGE - SIMPLICITY



TRADE STUDY RESULTS

- FREON TEMPERATURE CONTROL BY RADIATOR BYPASS
- SUBLIMATOR FOR HEAT REJECTION DURING ASCENT
- THERMAL STORAGE FOR IN-ATMOSPHERE TEMPERATURE CONTROL
- USE SECOND-SURFACE MIRROR FOR RADIATOR COATING ($\alpha = 0.24$, $\epsilon = 0.8$)

72-1766

ELECTRICAL POWER SUBSYSTEM SCHEMATIC
Free-Flying RAM

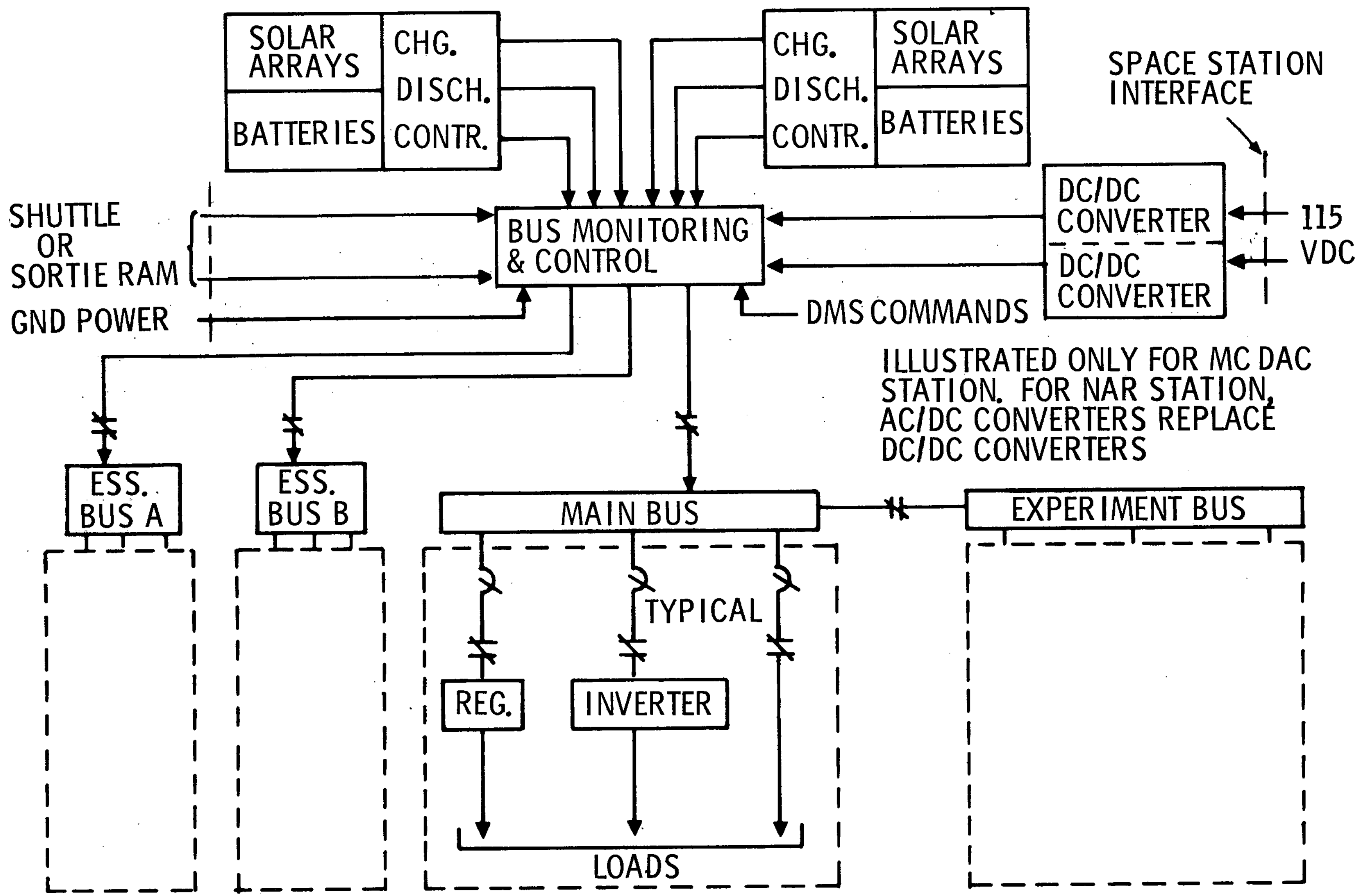
Solar arrays provide prime power generation for up to 2.8 kw with an area of 1,000 square feet. Power during periods of eclipse is provided by Ni-Cd batteries. The batteries are rated as 36 AH and sized for a 20% depth of discharge.

The electrical monitoring and control package is internally redundant and provides for fault sensing and mode selection by controlling the bus contactors. The distribution is at 28 vdc by means of three independent power channels: a main bus, and two essential (emergency) buses. The main bus powers all normal operations including an experiment bus and the essential buses satisfy the emergency considerations. Provisions are included to interface with the orbiter, sortie RAM, Space Station, and GSE.

A generally centralized conditioning concept is utilized. The distribution and conditioning provide: unregulated 28 vdc; ±5% regulated 28 vdc; and 115/200 vac, 400 Hz, for subsystems and experiments.

ELECTRICAL POWER SUBSYSTEM SCHEMATIC

Free-Flying RAM



72-1661

ELECTRICAL POWER SUBSYSTEM
Free-Flying RAM

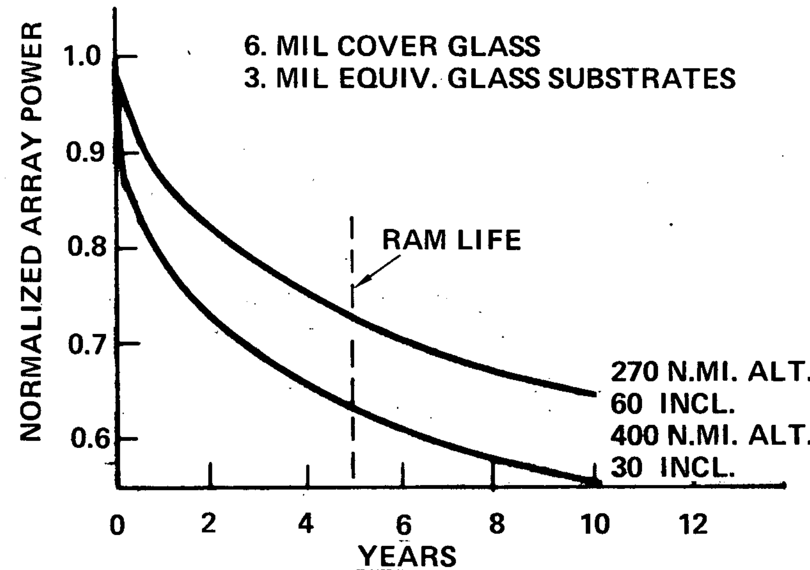
The sizing of solar arrays, in addition to load requirements, is a function of orbital parameters because of degradation due to radiation damage. The figure illustrates solar array degradation as a function of time for two orbits of interest. Array areas for equal EOL power at five years varies by 13%.

Trade studies were performed comparing: flexible rollout versus foldout versus rigid colar arrays; regenerative fuel cells versus Ni-Cd batteries; distribution at 28 vdc, 115 vdc, and 115 vac; and centralized versus decentralized power conditioning. Centralized power conditioning was selected on the basis of least cost and lowest weight and dissipation. Selection and rational are as shown for all other trade studies.

ELECTRICAL POWER SUBSYSTEM
Free-Flying RAM

BASIC SUBSYSTEM PARAMETERS

• POWER	TO 2.8KW MAX.
• DISTR. VOLTAGE	28 VDC
• CONDITIONING	28 VDC REG. 115 VAC, 400 HZ



SOLAR ARRAY OUTPUT VERSUS TIME

RATIONALE FOR SELECTION

• FLEXIBLE-ROLLOUT SOLAR ARRAYS	LIGHTWEIGHT, MINIMUM DEVELOPMENT, LONG LIFE
• NiCd BATTERIES (20% DOD)	MINIMUM DEVELOPMENT, MINIMUM COST, LONG LIFE CYCLE
• DISTR. VOLTAGE	MINIMUM DEVELOPMENT, COMMONALITY WITH RAM ELEMENTS

IMPORTANT TRADE STUDY RESULTS

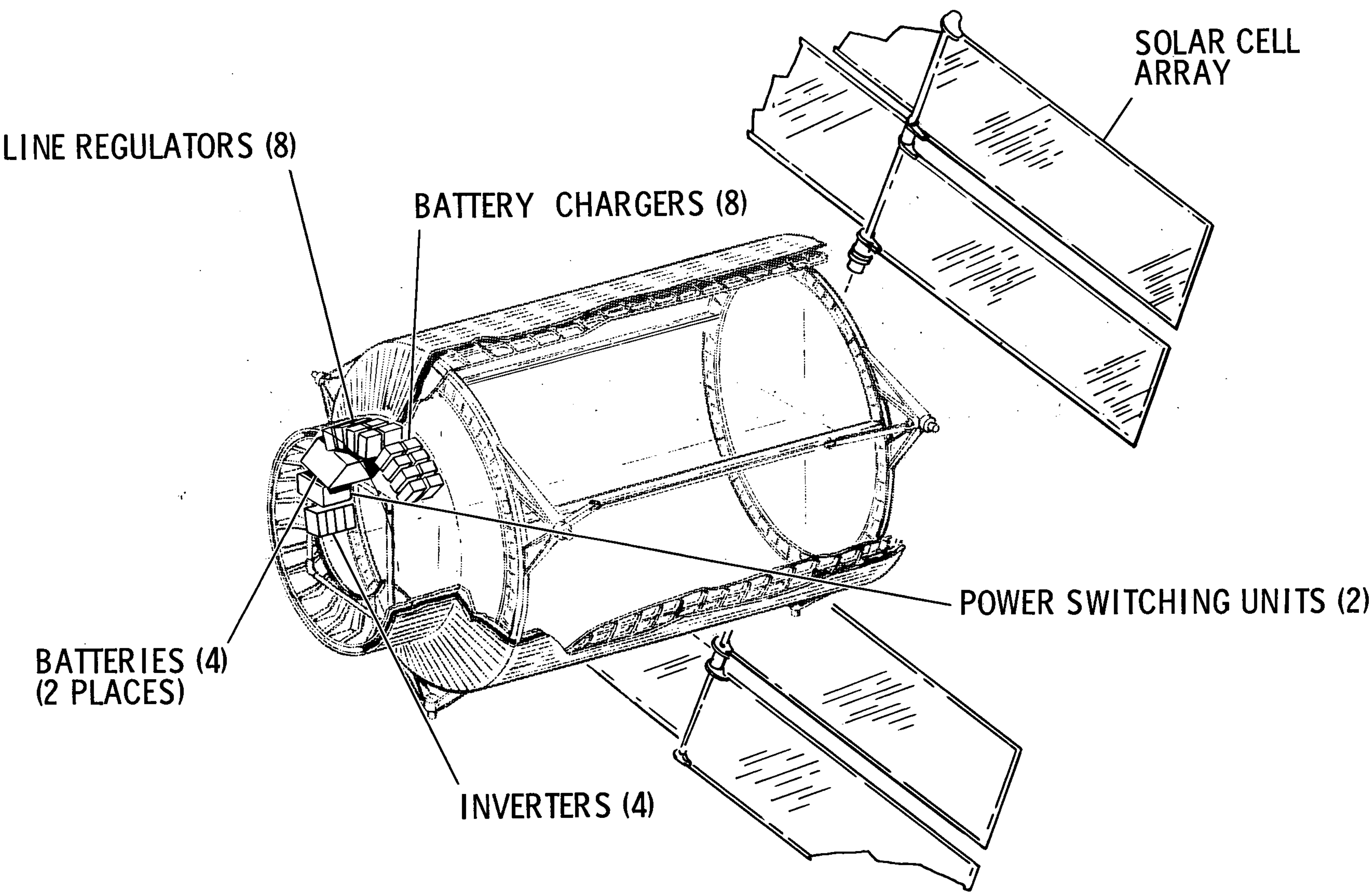
- FLEXIBLE-ROLLOUT SOLAR ARRAYS
- NiCd BATTERIES FOR ENERGY STORAGE
- 28-VDC DISTRIBUTION — REDUNDANT BUSES
- CENTRALIZED POWER CONDITIONING

72-1660

ELECTRICAL POWER
Free-Flying RAM

The prime source of power is flexible rollout solar cell arrays mounted to the primary structure at the aft or experiment end of the free-flying RAM. Solar cell area varies with experiment payload and operating mode (shuttle or station-supported). However, all storage drums are the same type developed by Hughes. Two drums are required for Large Space Telescope or long-term cryogenic experiment payload. A dragonfly arrangement (four drums) is used for the other three astronomy payloads. The array drums are stowed longitudinally along the exterior diameter. After erection 90 degrees, the arrays would be rolled out and capable of one-degree-of-freedom solar orientation by an electromechanical drive located at the base. Internal components, including batteries for power generation during eclipsed periods, are located in the 102-inch diameter utilities tunnel at the docking end of the RAM.

ELECTRICAL POWER
Free-Flying RAM



72-1802

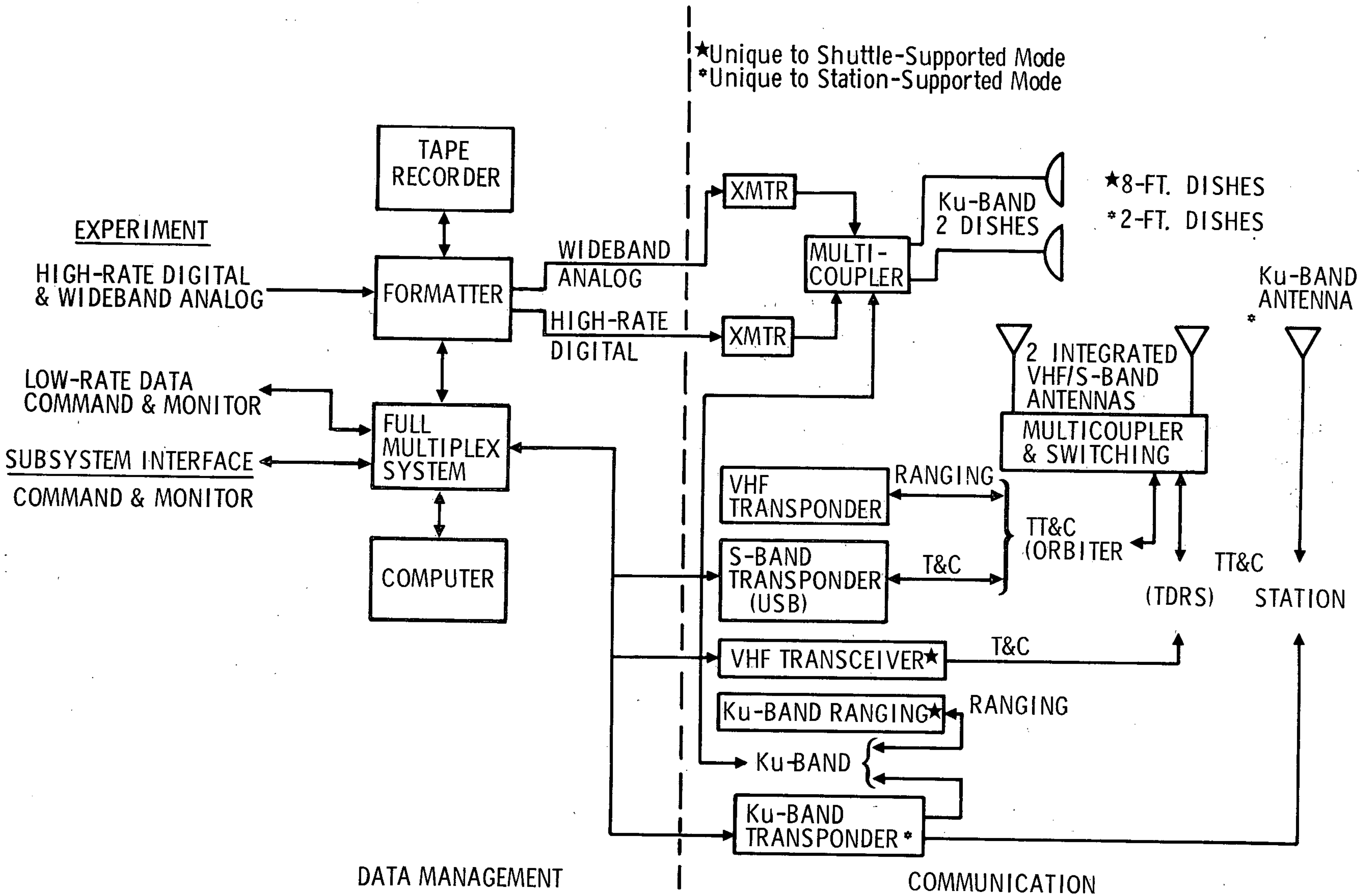
COMMUNICATIONS AND DATA MANAGEMENT SUBSYSTEM SCHEMATIC

Free Flying RAM

The basic data handling approach is digital buffer data storage and data relay to Space Station or ground. The buffer is a magnetic tape recorder that accepts data at high rates and, by tape speed reduction and demultiplexing, provides an output rate of 10 MBPS for transmission. A full multiplex digital data acquisition and command distribution system and a centralized computer configuration with floating point hardware are used for signal acquisition and processing.

Data relay is via TDRS using two 8-foot Ku-band dishes for shuttle-supported operations, or by means of two 2-foot Ku-band dishes for the station-supported mode. In addition to digital data, wideband analog is also transmitted for real-time calibration, adjustment, and control. Low-rate telemetry and command are via VHF/TDRS links for the shuttle-supported mode or a Ku-band link to Space Station for that operational mode. During rendezvous, telemetry and command to/from the orbiter are provided by S-band and ranging by a VHF ranging transponder.

COMMUNICATIONS/DATA MANAGEMENT SUBSYSTEM SCHEMATIC
Free-Flying RAM



72-1689

COMMUNICATIONS AND DATA MANAGEMENT SUBSYSTEM

Free-Flying RAM

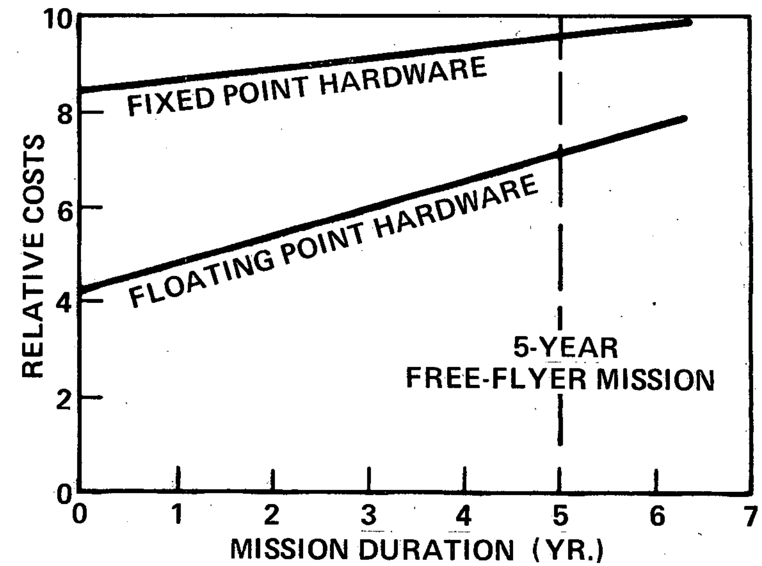
Fixed-point and floating-point hardware were considered in selecting a computer configuration. The chief advantage of floating-point hardware is a significantly lower cost for software development for processing algorithms typified by GN&C requirements. This is illustrated by the curves showing an approximate 2:1 cost advantage for floating point at time zero; however, floating-point hardware requires a larger memory, which results in greater power demands than for the fixed point. Assigning a cost penalty for energy consumption (solar array power is expensive) the cost advantage remains with floating-point hardware for a five-year mission.

Additional trade studies included: centralized versus dedicated computer configurations; onboard data compaction versus buffer storage; full multiplex versus hardwire versus hybrid, data acquisition, and command distribution; and modular versus monolithic software organization. The software trade study selected the modular software structure with modularity to the separable task level because it achieves the lowest total cost for RAM software. Selection and rationale for other trade studies are as shown.

COMMUNICATION & DATA MANAGEMENT SUBSYSTEM
Free-Flying RAM

BASIC SUBSYSTEM PARAMETERS

- SIGNAL CAPACITY — 2,200
- COMPUTER — FLOATING POINT HDW.
- BUFFER STORAGE — 0.1 TO 51 GB/ORBIT
- TRANSMISSION — 2 CH. 5 MHz ANALOG — 10 MBPS DIGITAL



COMPUTER CONFIGURATION SELECTION

RATIONALE FOR SELECTION

- FULL MULTIPLEX SYSTEM — LOWEST COST, REDUCED EMI, ADAPTABILITY & FLEXIBILITY
- CENTRALIZED COMPUTER — LOWEST PROGRAM COSTS
- MAGNETIC TAPE BUFFER — LOWEST COST, WEIGHT & POWER
- TDRS TRANSMISSION — LEVEL 1 GUIDELINES

IMPORTANT TRADE STUDY RESULTS

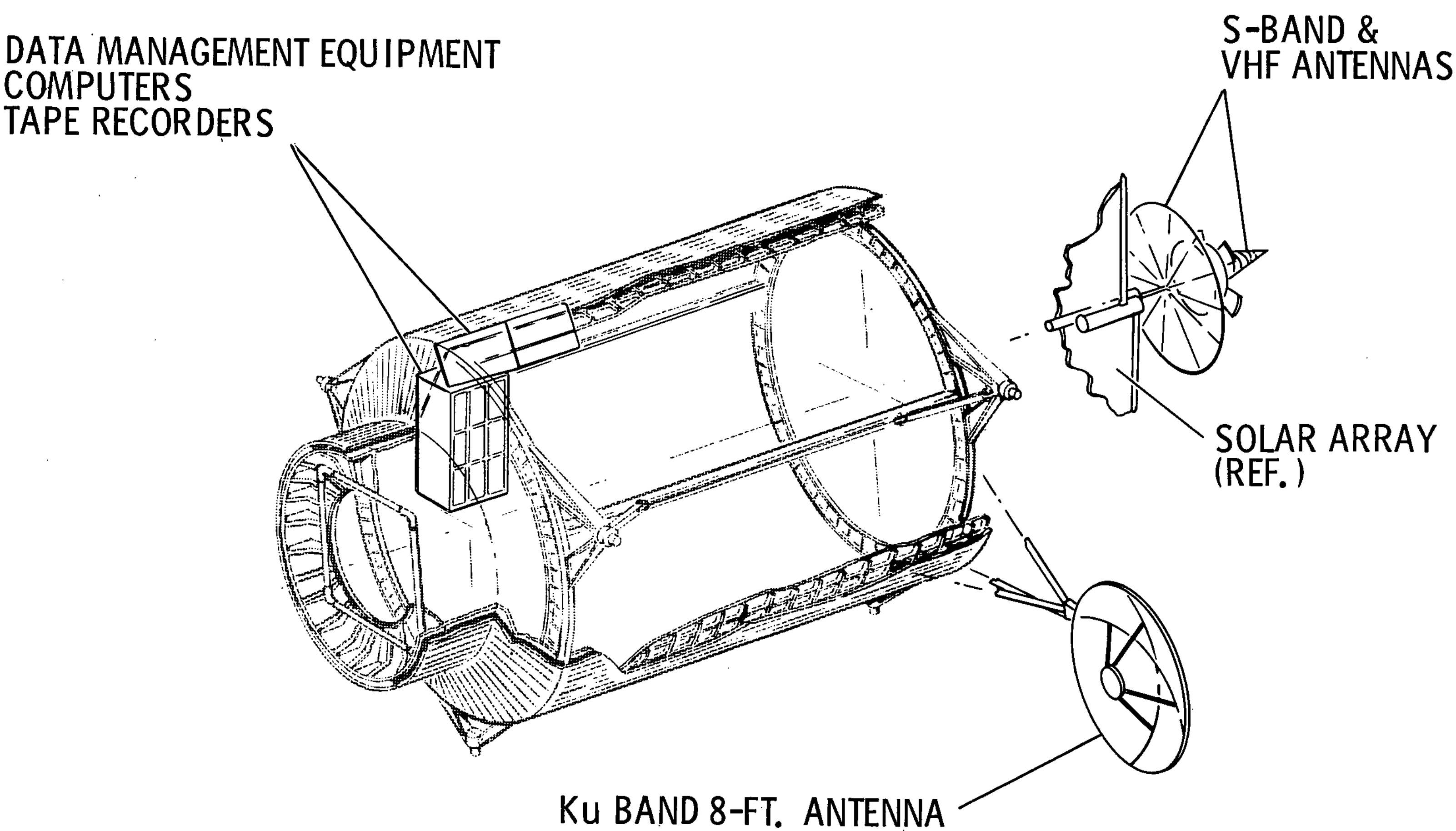
- FULL MULTIPLEX SYSTEM FOR DATA ACQUISITION & COMMAND DISTRIBUTION
- CENTRALIZED COMPUTER CONCEPT
- MODULAR SOFTWARE STRUCTURE
- MAGNETIC TAPE BUFFER STORAGE

72-1706

INFORMATION MANAGEMENT SYSTEM
Free-Flying RAM

Information management equipment is mounted in two cabinets mounted to the interior of the 135-inch diameter pressure shell of the free-flying RAM. The two equipment racks are hinged to swing out for servicing, replacement of components and access to the backside connectors. This also provides access to the pressure wall for the repair of punctures due to meteoroids, equipment, or other causes.

INFORMATION MANAGEMENT SYSTEM
Free-Flying RAM



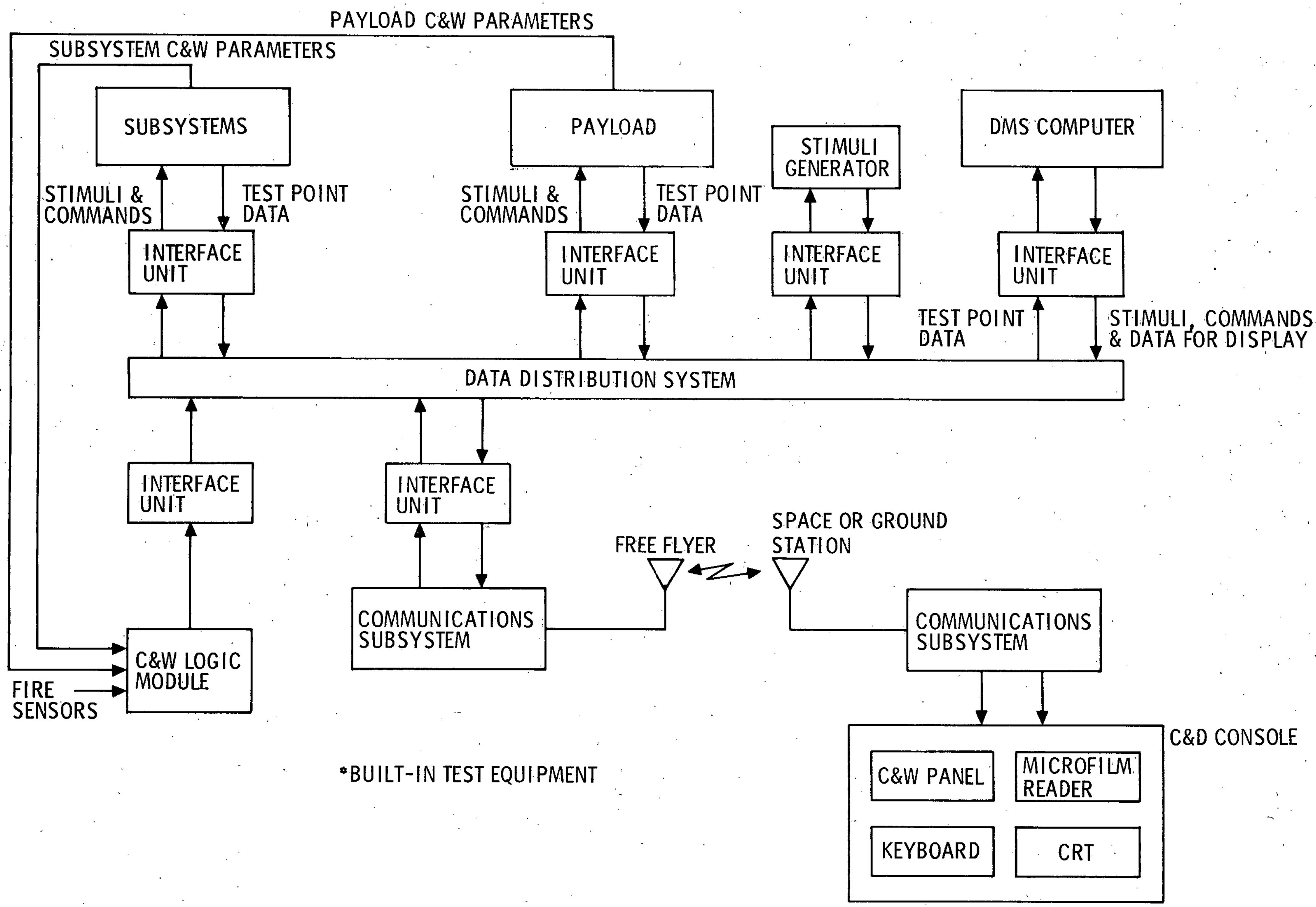
72-1801

ONBOARD CHECKOUT SUBSYSTEM SCHEMATIC
Free-Flying RAM

The OCS for the free-flying RAM is a semi-autonomous, flexible, job-oriented system. It performs repetitive functions such as status monitoring automatically while permitting man participation from the Space Station or ground, in those functions performed periodically, or on an on-demand basis, such as fault isolation, redundancy switching, and checkout.

The onboard checkout system uses the CDMS data processor, data distribution system, and interfacing units. It provides a stimuli generator to activate subsystems for checkout and fault isolation. It also provides a caution and warning logic module that monitors caution and warning conditions aboard RAM and interfaces with orbiter, sortie RAM, or Space Station during delivery and servicing. This function is performed concurrently with, but independent of, other checkout functions.

ONBOARD CHECKOUT SUBSYSTEM SCHEMATIC
Free-Flyer



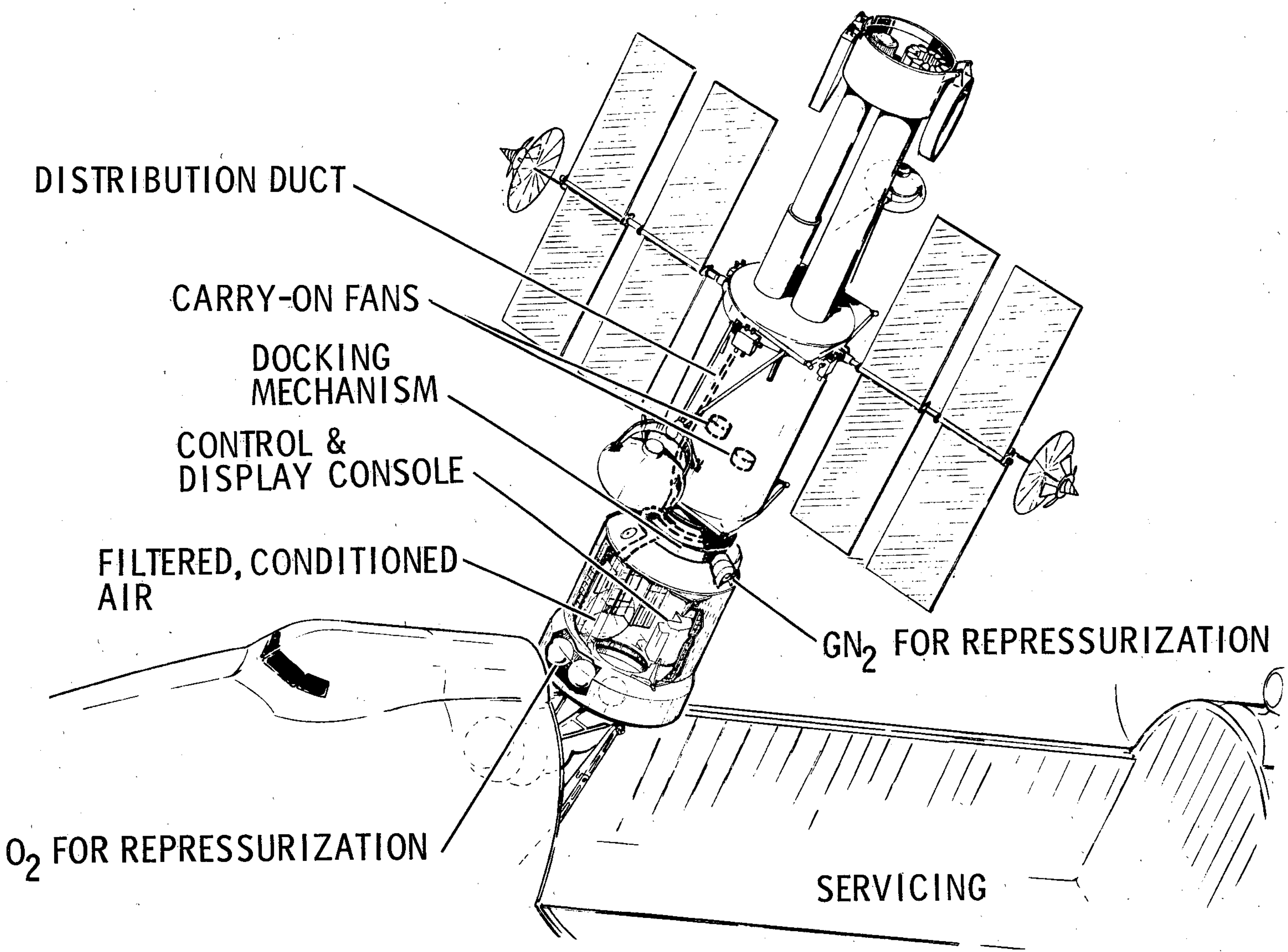
*BUILT-IN TEST EQUIPMENT

72-1700

HABITABILITY & EC/LS
Free-Flying RAM

Because the free-flying RAM is unmanned during all orbital operations except for initial deployment and periodic servicing, the requirements for habitability provisions and environmental control/life support are very limited. The illustration shows servicing in the shuttle-supported mode. The normal free-flying RAM attitude control subsystem keeps it stable while the orbiter rendezvous and docks. The Sortie RAM provides oxygen and nitrogen to repressurize the free-flying RAM because the free-flyer is evacuated during orbital operations and manned during servicing. The Sortie RAM provides conditioned atmosphere with special filtering to meet free-flying RAM cleanliness requirements. An air duct in the free-flying RAM, together with portable fans, provides air distribution. Air return is via the open hatch. Test and checkout operations are conducted from the display and control console in the Sortie RAM with assist by a crewman in the free flyer, as necessary. Mobility and restraint devices are provided in the free-flying RAM.

HABITABILITY & EC/LS
Free-Flying RAM



72-1758

GN&C SUBSYSTEM SCHEMATIC
Free-Flying RAM

The driving requirements for GN&C for the free-flying RAM are sub-arc-sec. pointing and preservation of orbital cleanliness. All-attitude pointing in an inertial reference, with a slew rate of 6 deg./min. and a rotational acceleration of 6 deg./min.^{2}, is provided in addition to intrasubsystem support of RCS torque and force commands, and solar panel and antenna steering intelligence. As illustrated, the guidance and navigation, stabilization and control, and onboard checkout software implementation is accomplished in the centralized DMS data processor.

All attitude sensing to 30 arc-sec. accuracy is provided by fixed-head star trackers updating a strapdown rate gyro package. This capability is used to position the free flyer within the experiment sensor acquisition capabilities. Subsequently experiment aspect error signals are used by the GN&C subsystem to position and maintain the vehicle to the required observational pointing accuracy and stability. The torquing complement consists of three double-gimbal control moment gyros (CMGs) which stabilize the free-flyer body/telescope combination to 0.5 arc-sec. This level satisfies 50% of the experiments. More stringent pointing requirements, beyond the CMG threshold capability, are satisfied, by either an experiment integral vernier of image motion compensation (IMC) or the shown modular addition of small trimming reaction wheels.

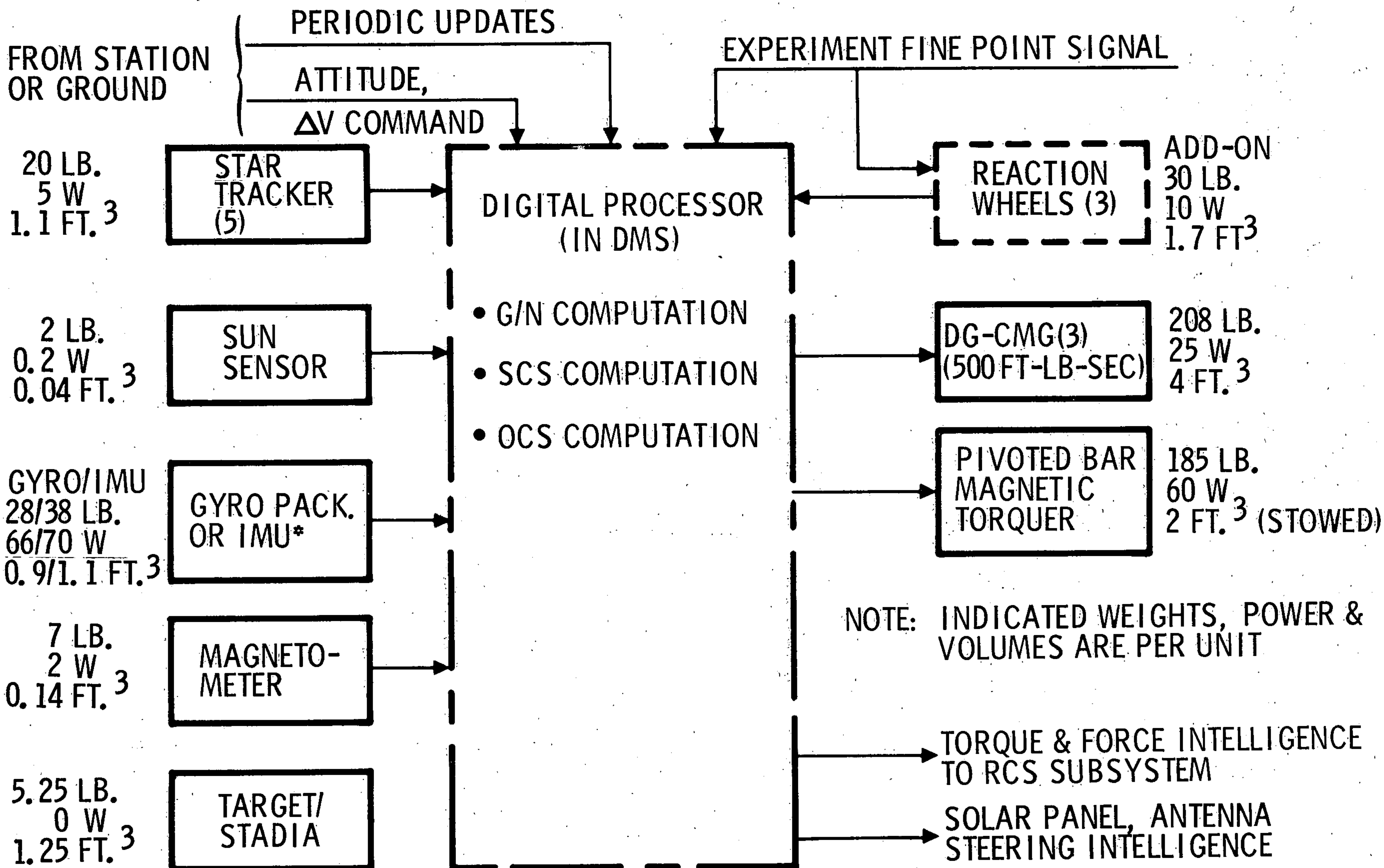
Desaturation of CMG momentum accumulation is provided by the magnetic torquer, which consists of a double-pivoted long (7 to 10 ft.) bar electromagnet. Continuous desaturation torque is provided via interaction with the earth's magnetic field (measured by the magnetometer).

The target/stadia is a passive device, derived from the Apollo program, to support shuttle active manual docking. The equipment complement includes redundancy of module assemblies, critical to module recovery operations, to offset critical equipment failures. Additional selective redundancy on star tracker, rate gyro package (internal) and CMGs to continue experiment operations after a failure is also provided to prevent an unscheduled shuttle service trip.

For station-supported and expendably launched free flyers, the measurement of RCS applied delta V is required in addition to measurement of RAM free flyer rotary state. This incremental requirement is satisfied by adding accelerometers to the rate gyro package. For station-supported free-flying RAMs, the addition is used in RAM active stationkeeping, rendezvous and dock all of which is directed by station integral G/N. For expendable booster launched free-flyers, the addition is used to monitor the execution of RCS imparted delta V in an orbit circularization maneuver.

GN&C SUBSYSTEM SCHEMATIC

Free-Flying RAM



*IMU FOR STATION SUPPORT, GYRO PACK FOR SHUTTLE SUPPORT.

NOTE: INDICATED WEIGHTS, POWER & VOLUMES ARE PER UNIT

72-179?

GN&C SUBSYSTEM
Free-Flying RAM

The basic subsystems parameters or requirements driving the design are given. Major trade issues were CMG, magnetic torquer, and star tracker type selection. A strapdown rate gyro package was selected relative to a gimbaled platform because of its better size and weight; high maneuver rate measurements are not required, thus eliminating the need for a gimbaled platform.

A three DG CMG complement was selected over a five DC CMG, because of its better performance over a spherical momentum envelope and essentially no singular torque output points, as well as its favorable size and weight characteristics.

Because of the significant reduction in weight realized, a pivoted type of magnetic torquer was selected over the fixed triad.

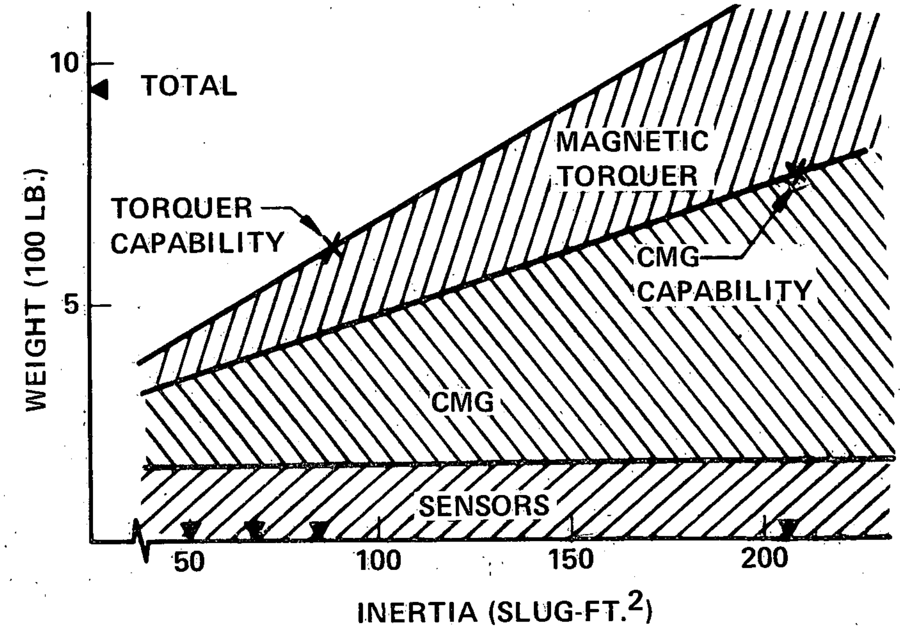
Based on the results of a reliability/maintainability/cost evaluation, fixed-head star trackers were selected in lieu of gimbaled star trackers. An increased sensitivity unit, imaging sixth magnitude stars versus fourth magnitude currently, plus pattern recognition on the corresponding star population is required. However, based on the current state of the art and projected advances in star tracker sensor capabilities, the desired star tracker characteristics are expected to be available in a time frame compatible with RAM requirements.

As illustrated, overall sizing is primarily driven by spacecraft difference between pitch/yaw and roll inertia. Sensors are not impacted, but CMG and magnetic torquer size are. The selected CMG is an available 500 ft.-lb.-sec. unit that yields about twice the needed momentum capacity for all but the one vehicle at about 200,000 slug-ft.^{2}. The magnetic torquer is sized to cover the three vehicles below 100,000 slug-ft^2. Additional torquer weight or partial use of gravity gradient dumping is required for the remaining free-flying RAM.

GN&C SUBSYSTEM
Free-Flying RAM

BASIC SUBSYSTEM PARAMETERS

- ORIENTATION - ALL-ATTITUDE INERTIAL
- POINTING (ARC-SEC.)
  ACQUISITION ±30
  OBS. ACCURACY ±1
  OBS. STABILITY
  CMG ± 0.5
  CMG/RW ±0.005
- CONTAMINATION - NON-RCS CONTROL PREFERRED



RATIONALE FOR SELECTION

- DG-CMG - BETTER PERFORMANCE & RELIABILITY RELATIVE TO SG-CMG.
- PIVOTED MAGNETIC TORQUER-WEIGHT REDUCTION RELATIVE TO FIXED TRIAD

IMPORTANT TRADE STUDY RESULTS

- FIXED HEAD STAR TRACKER - INCREASED RELIABILITY, REDUCED COST RELATIVE TO GIMBALED TRACKER
- MODIFICATION OF CURRENT SG-CMG TO DIRECT DRIVE DG TYPE RECOMMENDED
- CURRENT FINE POINT CAPABILITY CROSSOVERS ARE 0.5 ARC-SEC. FOR CMG & 0.005 ARC-SEC. FOR REACTION WHEEL ADD-ON

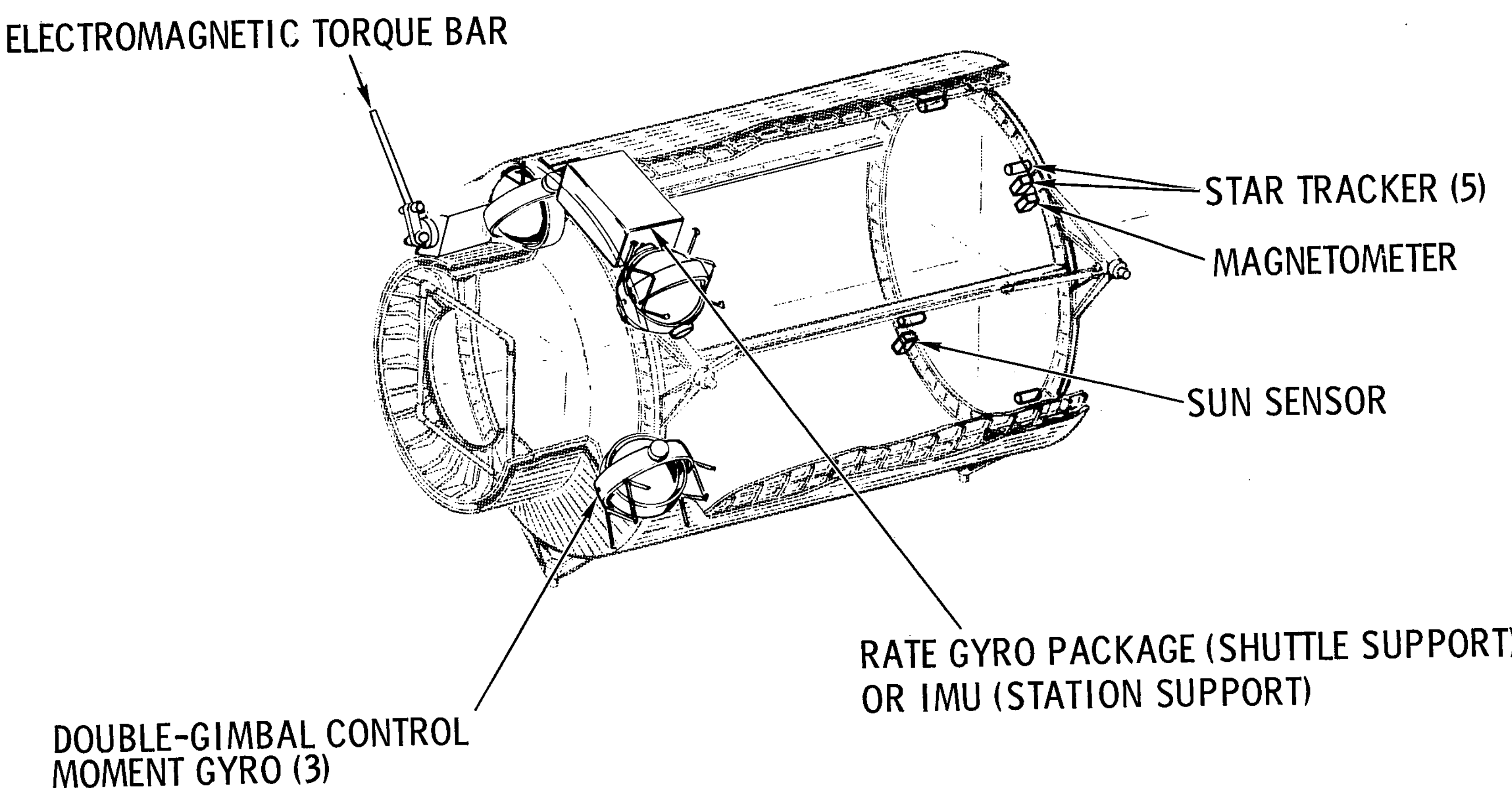
72-1800

GUIDANCE, NAVIGATION, AND CONTROL
Free-Flying RAM

Installation of the GN&C components in the free-flying RAM is shown. The three double-gimbal control moment gyros (CMGs) are mounted inside the 135-inch diameter pressure shell, adjacent to the conical bulkhead at the docking end. Additional GN&C equipment is packaged in a cabinet located between two of these CMGs. This cabinet would include either a rate gyro package for shuttle-supported operation or an inertial measuring unit if the free-flying RAM is station-supported. Volume is available near the conical bulkhead for the addition of two reaction wheels if fine pointing is required but not provided within the experiment. Additional GN&C components are located at the experiment end of the free-flying RAM.

The electromagnetic torque bar for momentum desaturation of the CMGs is stowed along the external meteoroid/radiator panels. Erection and two-degree-of-freedom orientation of the bar are adjacent to the docking interface.

GUIDANCE, NAVIGATION & CONTROL
Free-Flying RAM



72-1792

GN&C OPTIONAL FINE POINTING
Free-Flying Ram

The double-gimbal CMG is expected to yield ±0.5 arc-sec. stability, satisfying about 50% of the current free-flyer payloads. Payloads requiring more stringent pointing stability to 0.005 arc-sec. can be satisfied by a modular addition of small trimming reaction wheels (body pointing). The other option is the alternative use of some form of image motion compensation (IMC). This latter method of achieving pointing stability of 0.005 arc-sec. has not been investigated as part of the contractual effort.

An extensive three-dimensional simulation analysis was performed on the body point technique, including structural deformation of the telescope image path as well as the RAM body, CMG vibration due to unbalance, and CMG threshold limiting nonlinearities. The resulting performance characteristics for CMG alone and with the CMG/RW system are shown. It is seen that the CMG limitation is its threshold capability. The CMG/RW system limitation is the bandwidth limitation induced by flexure combined with the magnitude of rapidly applied torques. With small magnitude step torques applied, the body point system yielded ±0.001 arc-sec. stability. With a maximum step torque of 2 ft-lb., 0.01 arc-sec. was achieved. It is considered quite reasonable to limit rapid torques to one ft.-lb. or less, which indicates feasibility of meeting the 0.005 arc-sec. stability requirement.

Further analysis and verification of the body point technique are required.

GN&C OPTIONAL FINE-POINTING ANALYSIS
Free-Flying RAM

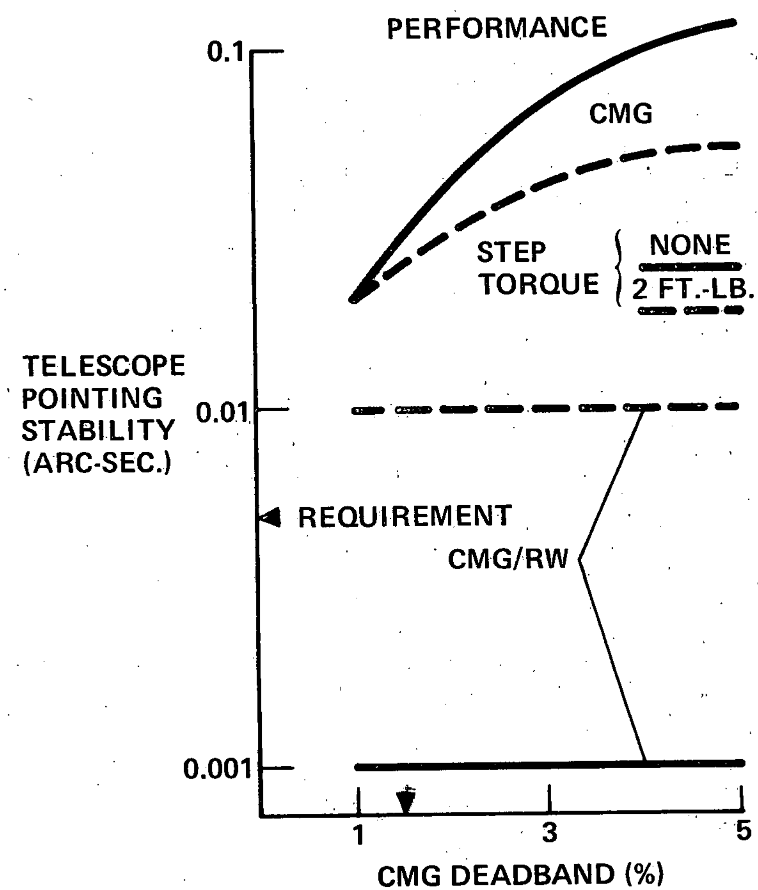
OBJECTIVE:
PROVIDE POINTING STABILITY TO ACCOMMODATE SPECIAL EXPERIMENTS TO 0.005 ARC-SEC. CMG CAPABILITY IS THRESHOLD-LIMITED TO APPROX. 0.1 ARC-SEC.

ALTERNATIVES:
TELESCOPE INTEGRAL VERNIER OR IMAGE MOTION COMPENSATION (IMC), OR BODY-POINT WITH MODULAR ADDITION OF REACTION WHEEL TRIAD

APPROACH:
ASSUMPTION IS THAT IMC WILL MEET REQT., BUT MAY BE MORE COSTLY RELATIVE TO BODY-POINT. PERFORMANCE DATA GENERATED FOR BODY POINTING.

BODY-POINTING SYSTEM DATA:

MOMENTUM	3 FT.-LB.-SEC.
TORQUE	1 TO 3 FT.-LB.
WEIGHT	90 LB.
SIZE	5.1 FT.^{3}
POWER	30 WATTS

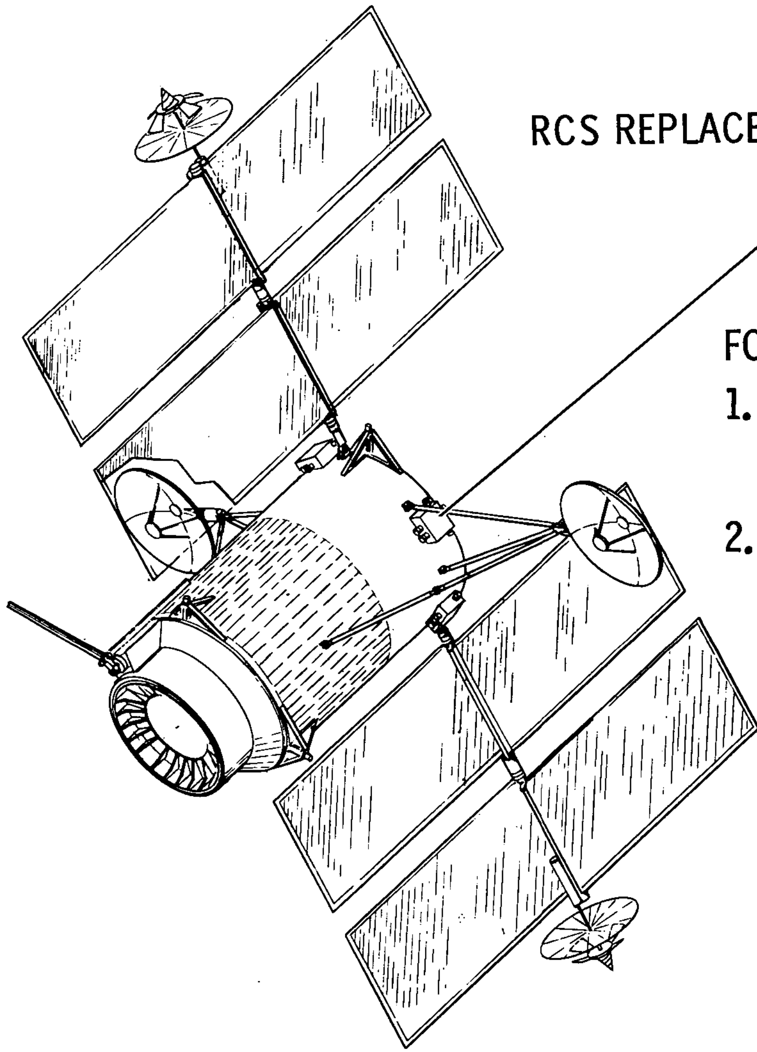


72-1812

PROPULSION/RCS
Free-Flying RAM

The baseline free-flying RAM, which is launched and serviced by the shuttle, has a propulsion/RCS consisting of four modules of monopropellant hydrazine, 25-lbf thrusters. Each module has six thrusters with supporting tankage and is removable as a unit. If the free-flying RAM is serviced by rendezvous and docking with a Space Station, eight additional thrusters and integral propellant tankage are added at the docking end. For a Titan-launched Large Space Telescoep, two 600-lbf. thrusters are added to the baseline for orbit circularization. Integral propellant storage provides the additional capacity required and reduces the size of the four RCS clusters to fit within a Viking shourd.

PROPULSION/RCS – SHUTTLE-LAUNCHED
Free-Flying RAM



FOR TITAN LAUNCH

1. ADD TWO 600-LB. THRUST ORBIT CIRCULARIZATION MOTORS & TANKAGE.
2. CHANGE FROM MODULARIZED TO CENTRALIZED PROPELLANT TANKAGE.

72-1791

PROPULSION/RCS SUBSYSTEM SCHEMATIC

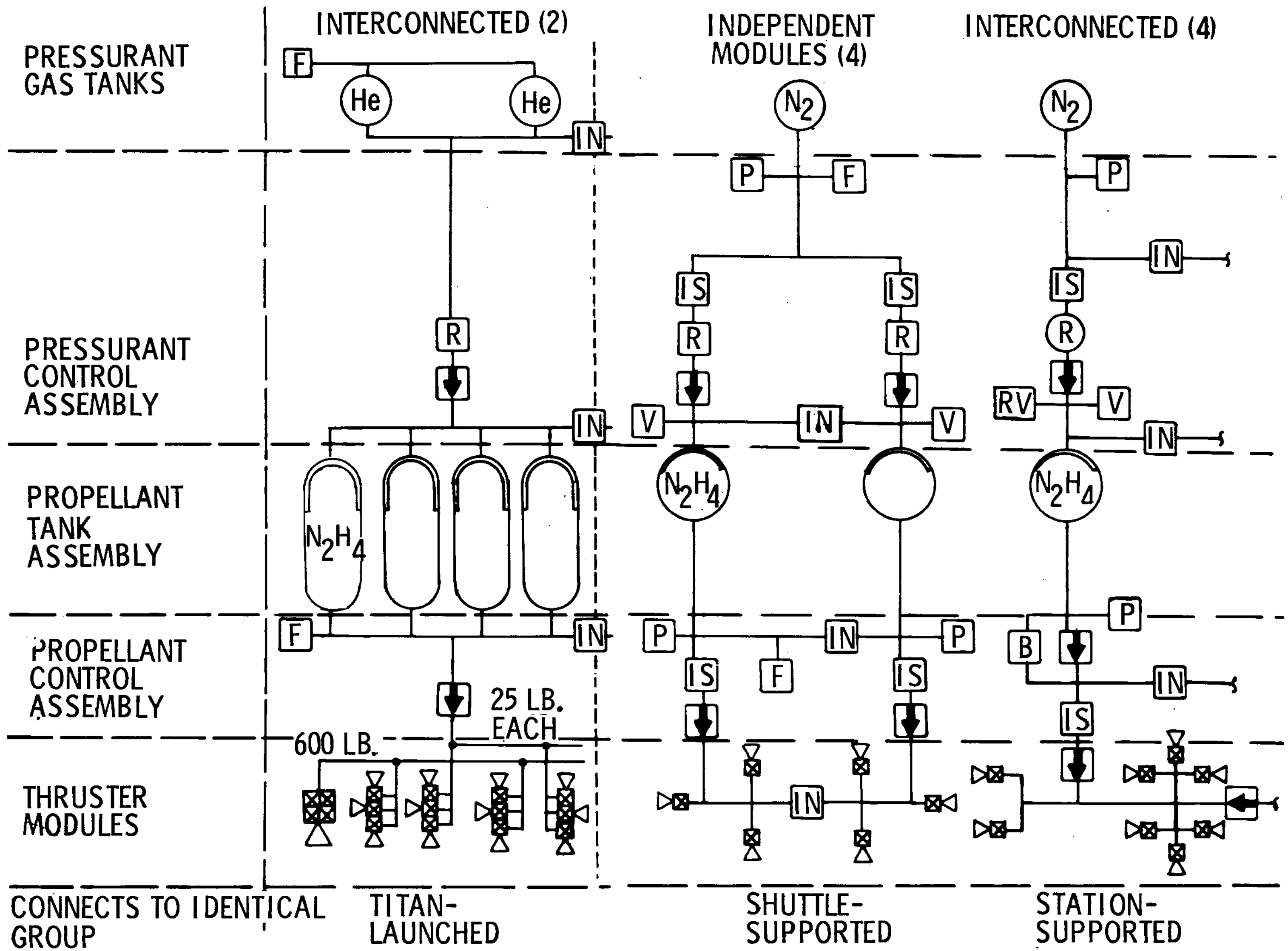
Free-Flying RAM

All free-flying RAMs, whether Titan-launched shuttle or station-supported, rely upon hydrazine monopropellant for their propulsive fuel. The fuel, selected by virtue of trade study finding, is stored in positive-expulsion, constant-pressure tankage selected primarily on the basis of the availability of flight- proven technology and hardware which support this choice. Dry nitrogen has been selected as the pressurant gas as the consequence of a trade study that identified N_2 with lowest cost, where small variations in weight and volume are not overriding considerations (as it is with the Titan-launched LST, where helium was selected for propellant pressurization).

All free-flying RAMs make use of the flight proven 25-lb. thrust RCS thrusters developed for the Titan transtage. These appear in four clusters of six each for the shuttle-supported free-flying RAMs, which require only attitude control. Four additional clusters of two each are supplied on station-supported free-flying RAMs to provide six-axis control (rotation plus translation).

Contamination considerations alone would probably preclude use of RCS for observational maneuvers? however, examination of the fuel weight per maneuver curves illustrated another consideration. A 100,000 slug-ft.^{2} vehicle maneuvering five times per day at a nominal rate of 6 deg./min. would consume 1.5 lb. of propellant per day or 270 lb. between projected six-month shuttle visits. By contrast, CMGs sized for maneuvering at that rate hold the ten-year propellant requirement to less than 270 lb. and minimize propulsion contamination from combustion products.

PROPULSION/RCS SCHEMATIC
Free-Flying RAM



72-1759

PROPULSION/RCS
Free-Flying RAM

The requirements for the propulsion/RCS on the free-flying RAM are derived from three modes of operation: shuttle-supported, station-supported, and Titan III-launched large space telescope (LST).

In the case of the shuttle-supported RAM, the RCS is required to provide for docking reactions, tumble capture, and attitude hold. The tumble could occur as the result of an aborted docking of the shuttle to the RAM with a resultant tipoff. The RCS would then be used to stabilize and reorient the RAM before another attempt at docking. Allowance is also made to stabilize the vehicle by the RCS to provide a backup mode in the event of failure of the CMG system normally used for RAM attitude hold. Propellant is provided for a two-week attitude hold with an RCS limit cycle operation before retrieval by the shuttle. The propellant quantity is substantially associated with the two-week attitude hold requirement while the thrust level is dictated by the dock reaction. The required rotary authority of 0.16 deg./sec. and the maximum angular momentum of the RAM vehicles determine the minimum required thrust level. The three functions of the shuttle supported RAM vehicles are to be accomplished with roll, pitch and yaw torque capability. (No displacement capability is required; hence four clusters of six thrusters each are adequate.)

The RCS is used to provide stationkeeping, rendezvous/departure, and docking/undocking for the station-supported RAM. The major propellant consumption is associated with stationkeeping due to the six- month operating time requirement without resupply. The thrust level requirement is dictated by the manual docking/undocking maneuver control acceleration requirements. The manual docking requirement is not anticipated to be a usual type of operation; however, provision for the recommended control authority is provided in the RCS design. Because of the translation requirement, an additional four clusters of two thrusters each are required.

The principal added requirement for the LST vehicle, above those for shuttle-supported RAM, is the delta V required (521 fps) to transfer the Titan-launched vehicle from a 90 deg. 400-n.mi. to a 400-n.mi. circular orbit. Two 600-lb. thrusters, acting through the spacecraft cg, provide the thrust compatible with a one-burn transfer.

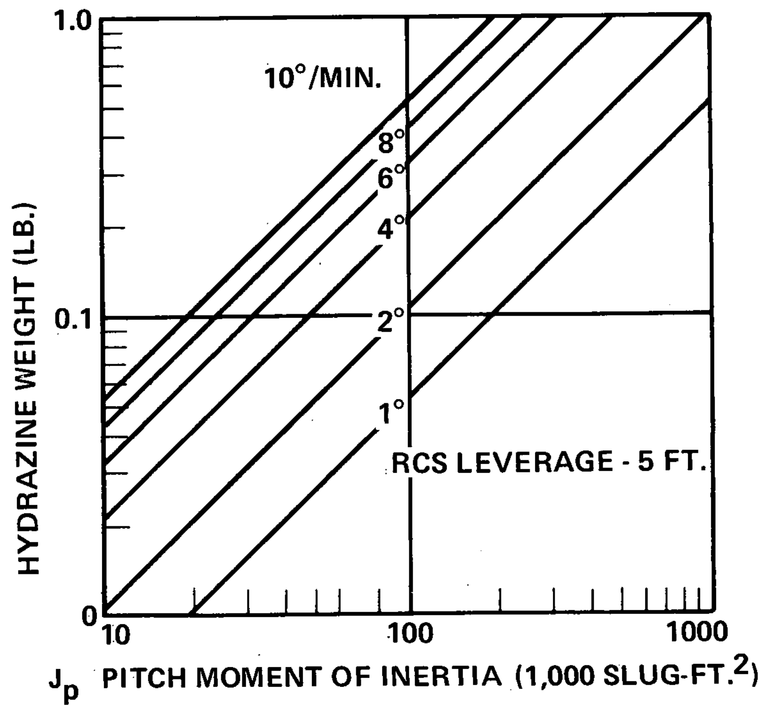
PROPULSION/RCS SUBSYSTEM
Free-Flying RAM

BASIC SUBSYSTEM PARAMETERS

- PROPELLANT - HYDRAZINE (N_2H_4)
- PROPELLANT TANKS - POSITIVE EXPULSION
- PRESSURANT - N_2 EXCEPT LST (He)
- RCS - 25-LB. THRUSTERS

RATIONALE FOR SELECTION

- PROPELLANT - GOOD I_{sp}, LOW CONTAMINATION, GOOD STORABILITY
- TANKS - PROVEN TECHNOLOGY, FLIGHT QUALIFIED
- PRESSURANT - N_2 LOWER COST WHERE WEIGHT & VOLUME NOT CRITICAL
- THRUSTERS - FLIGHT QUALIFIED (TRANSTAGE)



FUEL WEIGHT VS. VEHICLE SIZE PER MANEUVER

IMPORTANT TRADE STUDY RESULTS

- HYDRAZINE SELECTED OVER BIPROPELLANT
- ELASTOMER BLADDER FOR EXPULSION
- N_2 PREFERRED PRESSURANT GAS
- PVT PROPELLANT QUANTITY GAGE SELECTED

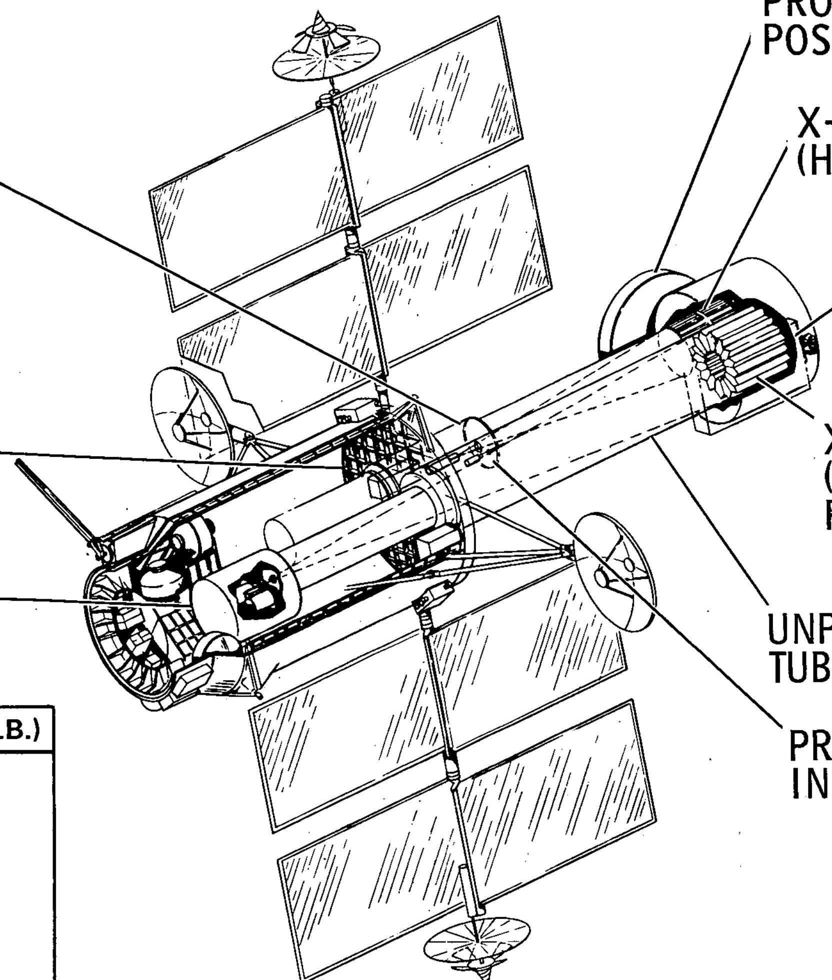
72-1798

FREE-FLYING RAM – EXPERIMENT INTEGRATION
X-Ray Stellar Astronomy

The representative x-ray stellar astronomy equipment consists of a high-resolution x-ray telescope, a large area x-ray telescope and four auxiliary arrays of independent instruments. The x-ray telescope primary mirrors and the auxiliary instrument sensors are located at the aperture end of the configuration. Two integrated tube/truss structures support the x-ray mirrors (and auxiliary instruments) with respect to focal point instruments. These may be of composite material in order to achieve a structural stability of 1 arc-sec. or better. The rigid composite tubes are mounted to an experiment-peculiar pressure bulkhead which, in turn, is mounted to the ring section of a free-flying RAM. Auxiliary instruments mounted around the mirrors include a proportional counter array, scintillation counter, crystal spectrograph, and a transient phenomena detector array.

The focal point instruments for the high-resolution x-ray telescope and the aspect telescope are located in a pressurizable tube about 20 feet from the x-ray mirrors. The instruments are mounted on rails to slide from the tube through the pressure bulkhead into the pressurizable compartment for access to high resolution and aspect sensor instruments. The large-area x-ray telescope instruments are mounted on an instrument change mechanism (turntable) enabling successive movement of the instruments into the x-ray focal area. The large-area x-ray telescope composite tube is unpressurized with a pressure door or gate near the focal point instruments. Location of the pressure gate at the end of the tube enables secure fastening to the pressure bulkhead and a smaller tube within the pressurized compartment. High heat dissipating experiment relocatable electronics are mounted in a rack away from temperature sensitive equipment. A contamination protection and thermal control compartment with a contamination cover is provided around the x-ray mirrors and the auxiliary instruments. Maintenance of aperture-located instruments will be by means of manipulators or EVA.

FREE-FLYING RAM – EXPERIMENT INTEGRATION
Stellar X-Ray Astronomy



ITEM	WEIGHT (LB.)
STRUCTURE	6,108
SUBSYSTEM	5,436
EXPERIMENTS	13,904
DRY WT.	25,448
RESID., RESERV. & EXPEND.	690
TOTAL	26,138

72-1790

FREE-FLYING RAM – EXPERIMENT INTEGRATION
LST – Stellar Astronomy

Free-Flying RAM – Experiment Integration

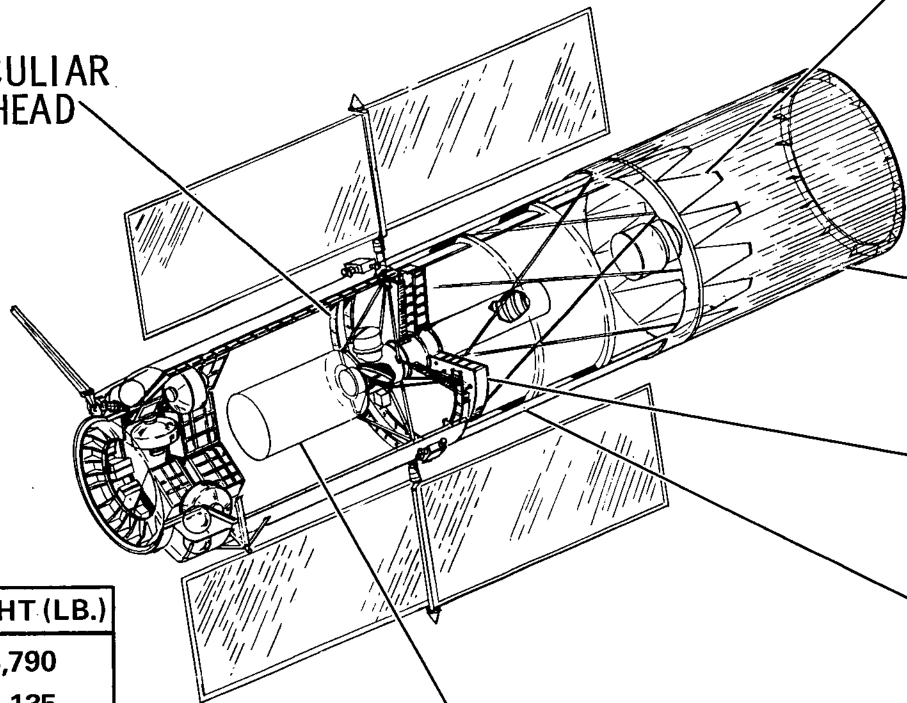
The optical telescope assembly (OTA) and the scientific instrumentation package (SIP) of the Large SpaceTelescope are mounted on an experiment-peculiar bulkhead. The pressure bulkhead is attached to a standard free-flying RAM basic structure. With the light shield retracted, the overall size is approximately a 12-foot diameter by 42.5 feet, which is compatible with a Titan IIID launch. The arrangement of subsystems are relocatable experiment electronics within the pressure compartment allows shirtsleeve access to all of the OTA/SIP instrumentation packages and the RAM subsystems. The compact solar array, optical telescope, and scientific instrumentation structure, together with rigid coupling to the RAM primary shell structure, produce a balanced configuration enabling maximum fine point stability; space is provided for add-on reaction wheels to augment basic RAM and OTA/SIP fine-pointing and stabilization.

The structural design of the OTA/SIP/RAM portions of the Large Space Telescope has been kept compatible with future use of graphite/epoxy or other composites if needed to improve stiffness and temperature control characteristics.

Space for optional propulsion to enable launch of the LST with Titan IIID is provided. Low-profile propulsion/RCS units are used together with propellant tanks, which are located around the docking tunnel. Small-diameter solar array drums and extension mechanisms are provided to enable clearance within the Viking shroud.

The LST configuration is compatible with Titan launch, as well as shuttle launch, servicing, and retrieval. For shuttle launch, propellant, extra engines, and extra propellant tanks may be offloaded.

FREE-FLYING RAM – EXPERIMENT INTEGRATION
LST Stellar Astronomy



ITEM	WEIGHT (LB.)
STRUCTURE	4,790
SUBSYSTEM	5,135
EXPERIMENTS	12,846
DRY WT.	22,771
RESID., RESERV. & EXPEND.	2,538
TOTAL	25,309

72-1787

FREE-FLYING RAM – EXPERIMENT INTEGRATION

Advanced Solar Astronomy

The photoheliograph telescope and precision star trackers are mounted external to the pressure bulkhead. The photoheliograph instrument housing, a 0.25-m XUV spectroheliograph telescope, a 0.5-m x-ray telescope, and the gimbaled coronagraph assembly are mounted to the pressure bulkhead within the pressurizable compartment. The pressure bulkhead is rigidly attached to the RAM shell structure. High heat load relocatable electronics and bulk processing equipment of the telescopes are located in two double racks isolated from thermally sensitive structures.

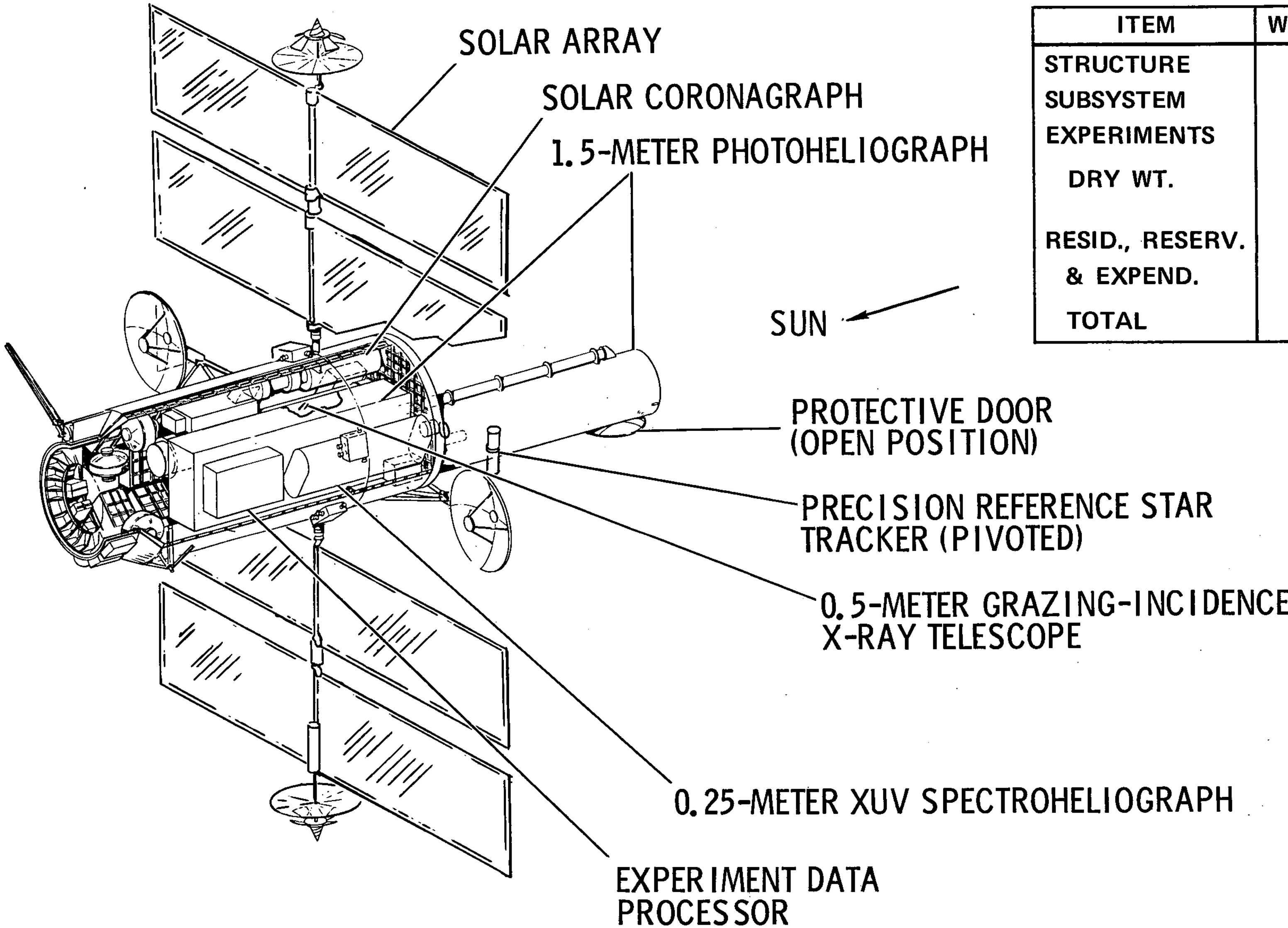
The standard RAM shell is extended by addition of a six-foot-long barrel section to obtain sufficient volume for the experiment equipment, manned access, and the RAM subsystems. Pressure gates on doors are provided for each aperture of the enclosed telescopes as well as for the photoheliograph telescope output light path. Special graphite/epoxy structures, adjustment devices, and optical instruments are provided to enable align the photogeliograph instrument housing, XUV spectroheliograph, and x-ray telescope axes to the photoheliograph telescope axis within 1 arc-sec. with jitter less than 0.1 arc-sec.

For shuttle-supported solar observatory missions, self-contained, replaceable RCS pods are used only for docking attitude control and CMG backup. Space is provided for reaction wheels to augment basic free-flying RAM CMG stabilization and experiment line-of-sight stabilization. Pointing and stabilization signals come from experiment-provided precision star trackers or from photoheliograph tracking sensors.

Large solar arrays, together with augmented electrical power equipment and thermal control equipment, enable simultaneous operation of all the telescopes and nonsequenced instruments.

The configuration provides minimum interference between solar arrays, TDRS antennas, and solar viewing telescopes during observations.

FREE-FLYING RAM – EXPERIMENT INTEGRATION
Advanced Solar Astronomy



ITEM	WEIGHT (LB.)
STRUCTURE	7,074
SUBSYSTEM	5,969
EXPERIMENTS	9,934
DRY WT.	22,977
RESID., RESERV. & EXPEND.	690
TOTAL	23,667

72-1788

FREE-FLYING RAM EXPERIMENT INTEGRATION

High-Energy Stellar Astronomy

To handle all potential high-energy experiments and missions scheduled for this module, an eight-foot barrel section (sidewall segment) is added to the standard free-flyer module, together with a pressure dome. The perspective shows representative equipment integrated within the pressurizable shell. A grazing-incidence telescope, aspect telescope, nine asymmetric crystal cone spectrometer polarimeters, and a high-resolution gamma-ray spectrometer array are attached to an experiment mounting structure. Adjustment capability to parallel telescope and instrument axes to the axis of the aspect telescope is provided. The mounting structure is connected to the RAM shell via the end ring or intervening supports. Other combinations of high-energy equipment, including a long Venetian blind telescope, can be accommodated within the shell.

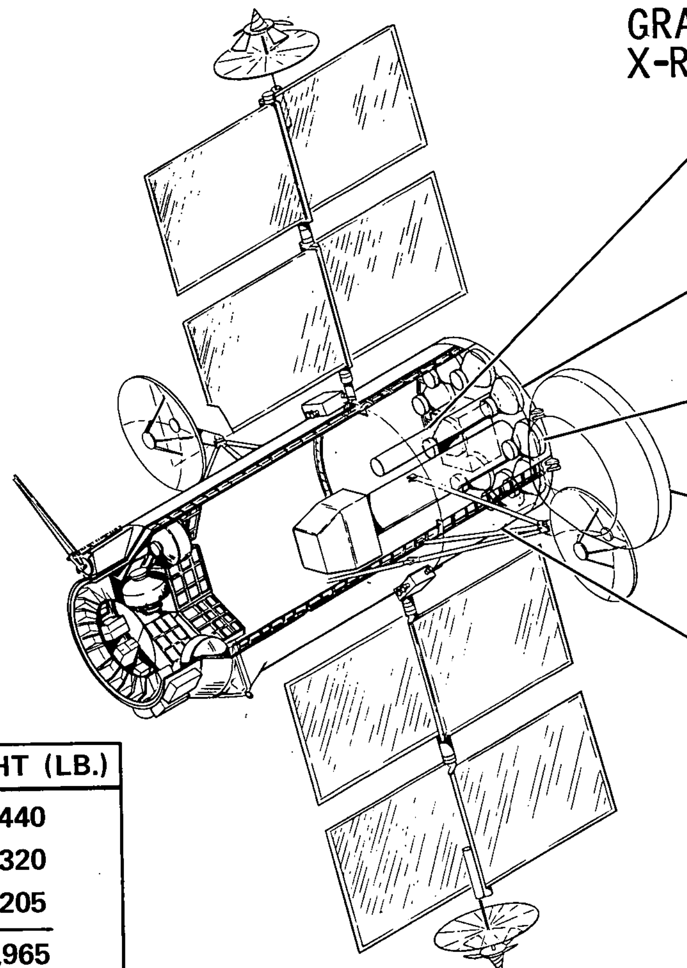
Complete shirtsleeve access is available to all telescopes, relocatable experiment electronics (in a double rack), and RAM subsystems.

The pressure dome cover, solar arrays, and antennas are arranged for minimum interference to each other. The pressure dome and an access hatch cover protect instruments from contamination during transport to orbit.

The RAM shell features integrated structure, micrometeoroid shell, and thermal radiators to minimize weight. Pod-mounted RCS equipment is used only for docking attitude control and CMG backup to minimize contamination. The pressure dome cover is closed in the presence of contaminants.

The omni-envelope of antenna patterns enables real time search, pointing, and "rocking" control to enable observer control remotely from earth-based sites without loss of communications. The higher heat dissipating experiment relocatable electronics rack is separated from temperature-sensitive telescopes and instruments to avoid structural deformation or equipment degradation.

FREE-FLYING RAM — EXPERIMENT INTEGRATION
High-Energy Stellar Astronomy



ITEM	WEIGHT (LB.)
STRUCTURE	7,440
SUBSYSTEM	5,320
EXPERIMENTS	3,205
DRY WT.	15,965
RESID., RESERV. & EXPEND.	690
TOTAL	16,655

72-1789

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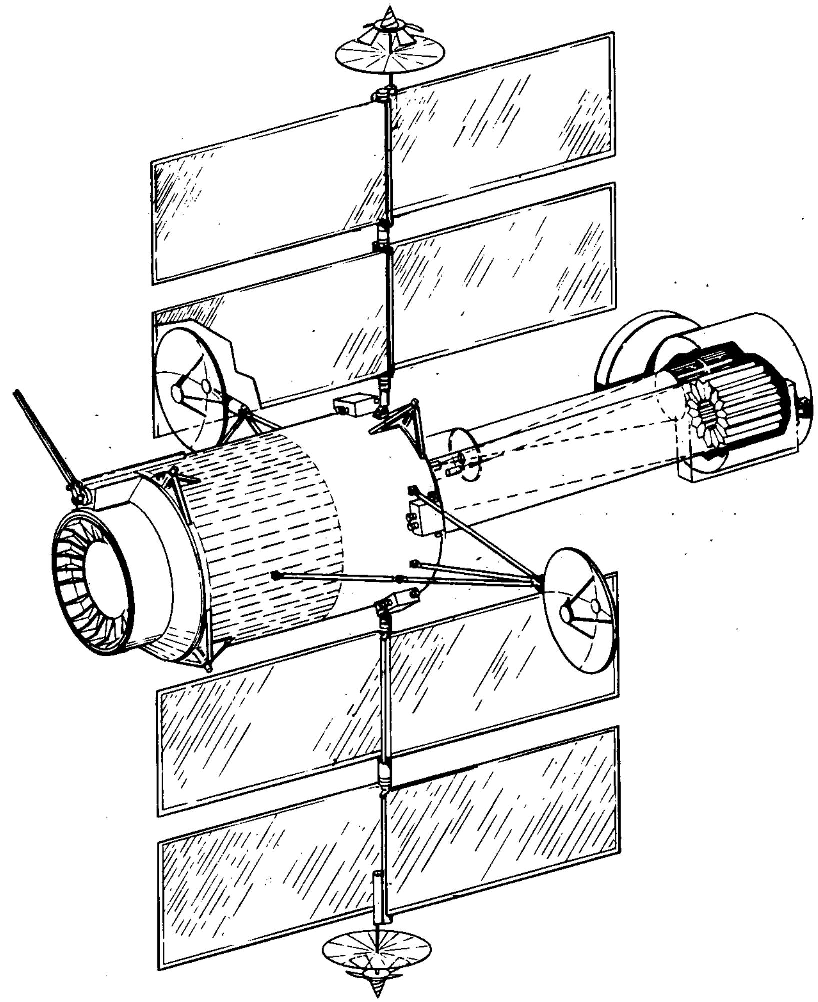
FREE-FLYING RAM INTERFACES

The free-flying RAM may be operated in either a shuttle or Space Station-supported mission mode. In the former case, a Sortie RAM with a docking adapter on the aft (+X) end is used for servicing. The interface functions are identical in the two cases with one exception. Shuttle-supported free-flying RAMs have very low propulsion requirements and the RAM has a five-year supply of propellants aboard. There is, therefore, no need for resupply of propellant or GN_2 pressurant during periodic visits. Redundant connections are provided for each of these for station-supported servicing. These connect points are external to the pressurized volume and are remotely connected and disconnected.

A docking target on the free-flying RAM is aligned with the docking telescope on the servicing vehicle. Repressurization lines for atmospheric oxygen and nitrogen are provided because the free-flying RAM is evacuated during orbital operations and manned during servicing. A single pipe provides conditioned air to the free-flying RAM; air return is through the open hatch. Redundant electrical power buses and data connections to the multiplex data system are provided for checkout, control, and caution and warning circuits. An air pump-down or bleed-down pipe is provided for evacuation following servicing. The air is scavenged in the station-supported mode only.

FREE-FLYING RAM
Interfaces

FREE-FLYING RAM - SHUTTLE FREE-FLYING RAM - SERVICE MODULE INTERFACES
2 DC POWER BUSES, 28 V, 4.8 KW AVG. 2 DATA CONNECTORS, MULTIPLEX SYSTEM 4 36-PIN HARDWIRE CONNECTORS, CONTROLS/ CAUTION & WARNING 1 ATMOSPHERE SUPPLY 2 REPRESSURIZATION LINES, O_2 & N_2 1 AIR PUMPDOWN PIPE 1 DOCKING TARGET
FREE-FLYING RAM - STATION ADD:
2 PROPELLANT LINES, HYDRAZINE 2 HIGH-PRESSURE GAS LINES, GH_2



72-1695

FREE-FLYING RAM ORBITAL OPERATIONS

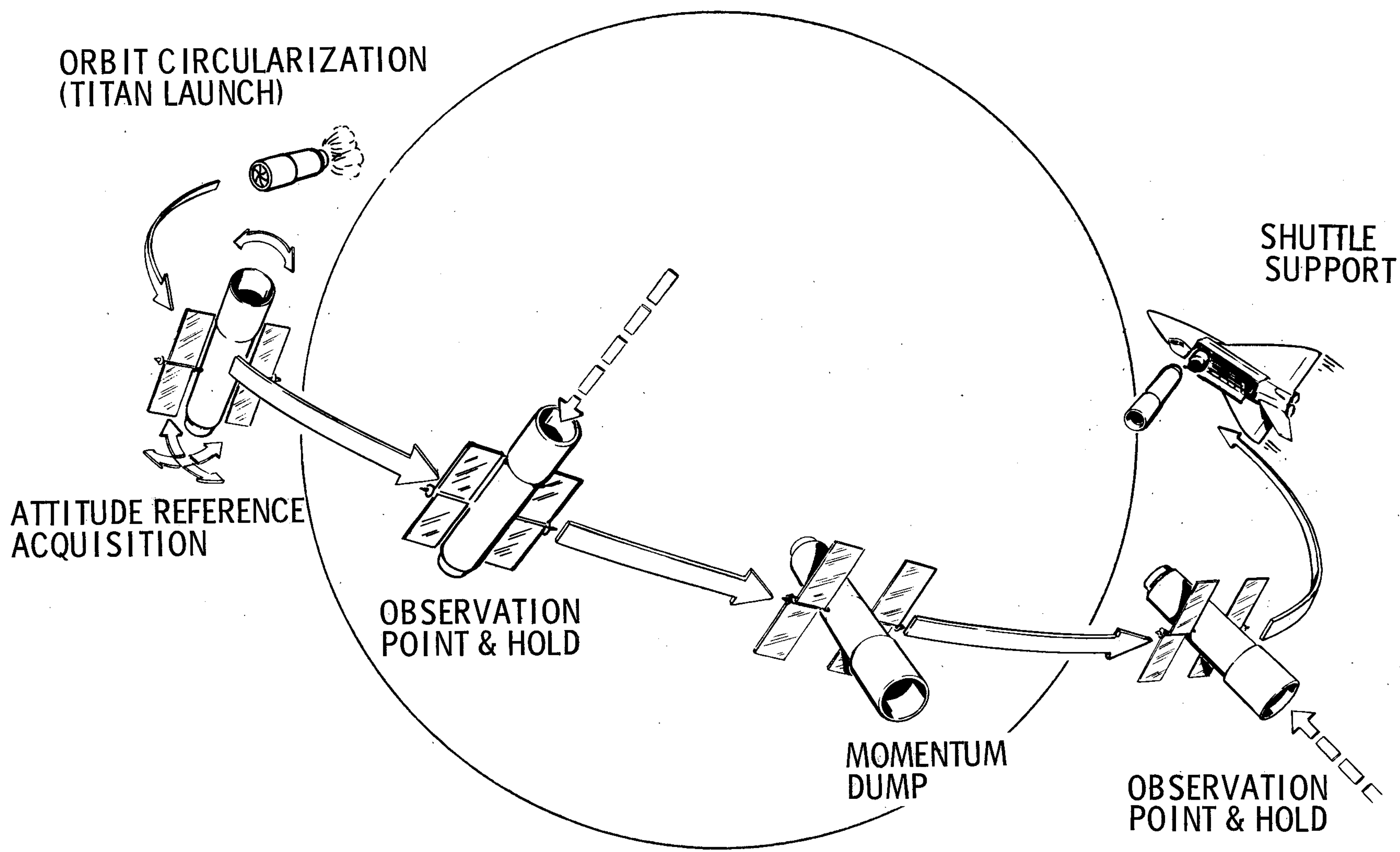
Dark Side Observation

Orbital operations for the free-flying RAM (Large Space Telescope) are summarized on the chart. Ascent phase operations are unique for the LST; however, on-orbit operations are similar for each of the representative free-flying RAMs. The free-flying RAM is shown after insertion into an elliptic orbit by a Titan IIID. Circularization at the operational orbit altitude is achieved by the RAM propulsion/RCS subsystem. Shuttle- launched free-flying RAMs are delivered to circular orbit by the orbiter and do not require RAM-provided orbit circularization. When the RAM reaches its operating orbit, solar arrays are deployed, communications activated, and handover of attitude control from the RCS to the momentum exchange control system occurs. The scientific instruments and telescope are activated, and a systematic checkout of instrument, telescope and free-flying RAM subsystem functions is made. After sufficient time has elapsed for contamination clearing, the telescope is opened and a series of observations of selected celestial objects is made to verify each instrument.

After the on-orbit preparation phase has been completed, the free-flying RAM begins its observation program. Observations of a celestial target are preceded by a period of momentum dumping and the slewing of the RAM to the target. The duration of the momentum dumping period is a function of the angle between the line of sight to the target and the perpendicular to the orbital plane, as well as the number of orbits of continuous pointing required.

About two years after Titan IIID launch, a manned shuttle sortie flight performs rendezvous with the free-flying RAM in preparation for maintenance and servicing operations. Maintenance is performed from a sortie RAM carried to orbit with the shuttle. Subsequent maintenance revisits are made as required for the remainder of the mission. A nominal revisit interval of six months is envisioned. After five years, the free- flying RAM can be retrieved by a manned shuttle flight and refurbished for subsequent missions.

FREE-FLYING RAM ORBITAL OPERATIONS
Dark Side Observation

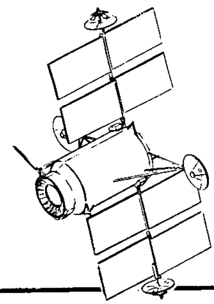


72-1773

FREE-FLYING RAM CAPABILITY

The free-flying RAM element capability is summarized opposite. Adequate volume is provided within the pressurizable shell for the accommodation of subsystems and experiment sensors. The experiment-provided pressure bulkhead closure provides for both internal and external sensor mounting. Electrical power from solar arrays is used for subsystems and experiments. Heat rejection through external radiator/micrometeoroid protection panels. Both digitai and analog data transmission RF channels are provided. Fine-pointing capability is provided by control moment gyros to the values shown. More stringent requirements must be met by the experimenter equipment by the use of, for example, image motio compensation techniques, or trimming reaction wheels. The reaction control subsystem (RCS) stabilizes the RAM during shuttle docking maneuvers and provides for rendezvous, docking, and stationkeeping needs when the free-flying RAM is operated with a Space Station.

FREE-FLYING RAM CAPABILITY



SUBSYSTEM PARAMETER	REQUIRED BY RAM	AVAILABLE TO USER	TOTAL
STRUCTURAL VOLUME ($FT.^3$)	1,090	920	2,010
HEAT REJECTION (1,000 BTU/HR.)	6	5	11
ELECT. POWER (AVG. KW)	0.8 TO 1.9	1.3 TO 2.0	2.8
DATA STORAGE BUFFER (BITS)	–	UP TO 5×10^{10}	UP TO 5×10^{10}
DATA TRANS.			
- 10^6 B/SEC.	–	DIGITAL UP TO 10	10
- MHz	–	ANALOG 2 X 5	2 X 5 MHz
DATA PROCESSING			
- MEMORY WORDS	15,000	9,000	24,000
- TIME (MSEC./SEC.)	520	480	1,000
POINTING ACCURACY (ARC.-SEC.)	–	1.0	–
STABILITY (ARC.-SEC./OBS.)	–	0.5	–
SLEW RATE (DEG./MIN.)	–	6	–
RCS STORED IMPULSE			
- SHUTTLE SUPPORTED (LB. SEC.)	22,000	–	22,000
- STATION SUPPORTED (LB. SEC.)	110,000	–	110,000

72-1756

SUMMARY

W.W. Withee

RAM PROGRAM OBJECTIVES IMPLEMENTATION

APPLICATIONS OF STUDY RESULTS

RAM PROGRAM IMPLEMENTATION FLEXIBILITY

72-1818

RAM PROGRAM OBJECTIVES IMPLEMENTATION

Information on the following charts will describe how some of the major program objectives called out in the beginning of the briefing were implemented and their results.

Approaches to minimizing the overall development and production costs of the RAM elements will be summarized as well as the means to achieve low early-year funding. A major contributor to realizing minimum costs is the use of common subsystems both from other space systems and within the RAM project itself. RAM subsystems common to other space systems will be identified as well as the ones which are common to each of the RAM elements.

The versatility of the RAM elements and the evolution of their capability starting with a sortie RAM and its several applications through all the pressurized modules and including the free-flying RAM will be described.

RAM PROGRAM OBJECTIVES IMPLEMENTATION

MINIMUM COST

LOW EARLY-YEAR FUNDING

COMMONALITY

VERSATILE OPERATIONS

GROWTH

72-1815

MINIMUM COST PHILOSOPHY

High costs have accrued to the space program in the past because of the multiplicity of spacecraft development programs and from the relatively large quantity of flight vehicles produced. RAM program philosophy provides for the accommodation of a wide variety of payloads in vehicles developed in an integrated evolutionary program. This approach minimizes cost through the orderly development of RAM elements wherein substantial cost benefit results from the high degree of commonality between module types. Commonality was emphasized throughout the study both within the RAM project, as well as with other NASA projects such as the Shuttle and Skylab. The RAM concept minimized the quantity of flight articles through refurbishment, conversion, and reuse. Modularity of subsystem capability also contributes to cost savings in vehicle production.

Flight failures is an area that has been costly in the past in terms of reflights or loss of objectives. The RAM systems concept minimizes these losses by onboard maintenance of inflight failures or minimum cost rerun of the mission through reuse of the module.

Testing also has represented a significant portion of development costs in the past. The RAM concept proposes, in addition to maximum use of developed and qualified hardware, system test of flight articles, test article refurbishment and conversion, and incorporation of a unified test plan for added efficiency.

Finally, in the Phase B RAM study cost has been emphasized and used as a principal criterion in tradeoff studies.

MINIMUM COST PHILOSOPHY

HIGH-COST AREA	COST MINIMIZATION
• MULTIPLE HARDWARE DEVELOPMENT	• INTEGRATED EVOLUTIONARY DEVELOPMENT PROGRAM • COMMONALITY
• MULTIPLE HARDWARE FLIGHT ARTICLES	• REFURBISHMENT & REUSE • CONVERSION • MODULARITY
• FLIGHT FAILURES	• ONBOARD MAINTENANCE • REUSE
• SYSTEM TEST	• TEST FLIGHT ARTICLES • REFURBISHMENT & CONVERSION • UNIFIED TEST PLAN
• COST CRITERIA NOT EMPHASIZED IN PROJECT DEFINITION	• COST PRINCIPAL CRITERION IN TRADE STUDIES

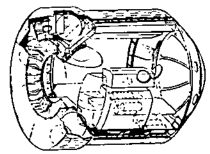
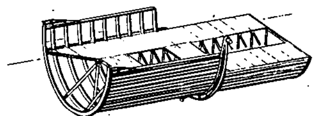
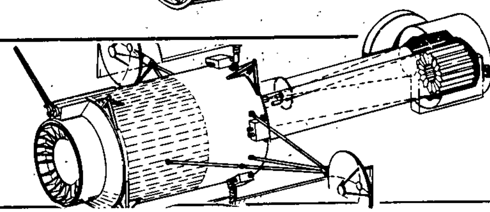
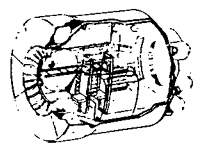
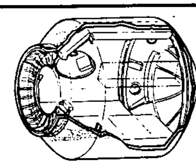
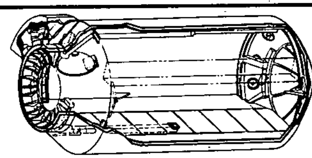
72-1730

RAM ELEMENT COSTS

Development and unit costs for the various RAM elements are shown in the accompanying chart. The development costs shown under "integrated development" are for a typical program, where elements are phased in the sequence shown. The first element to use a common piece of hardware incurs the full development cost (first user concept) and no prorating or allocating development costs are made. As long as the sortie RAM is development first, the sequence shown can be rearranged somewhat with the same resulting costs. The "individual development" case is the cost of each element for a completely independent program with no commonality of hardware elements or components.

Unit costs for RAM elements are not affected by integrated or individual development.

RAM ELEMENT COSTS

RAM ELEMENT			UNIT COST ($M)	INTEGRATED DEVELOPMENT COST ($M)	INDIVIDUAL DEVELOPMENT COST ($M)
SORTIE RAM			23.4	193	208
PALLET			1.3	11	12
FREE FLYING RAM			23.4	128	189
RAM SUPPORT MODULE			24.1	43	216
SORTIE PAYLOAD MODULE		18 FT.	5.6	10	61
STATION ATTACHED PAYLOAD MODULE		32 FT.	10.7	32	118

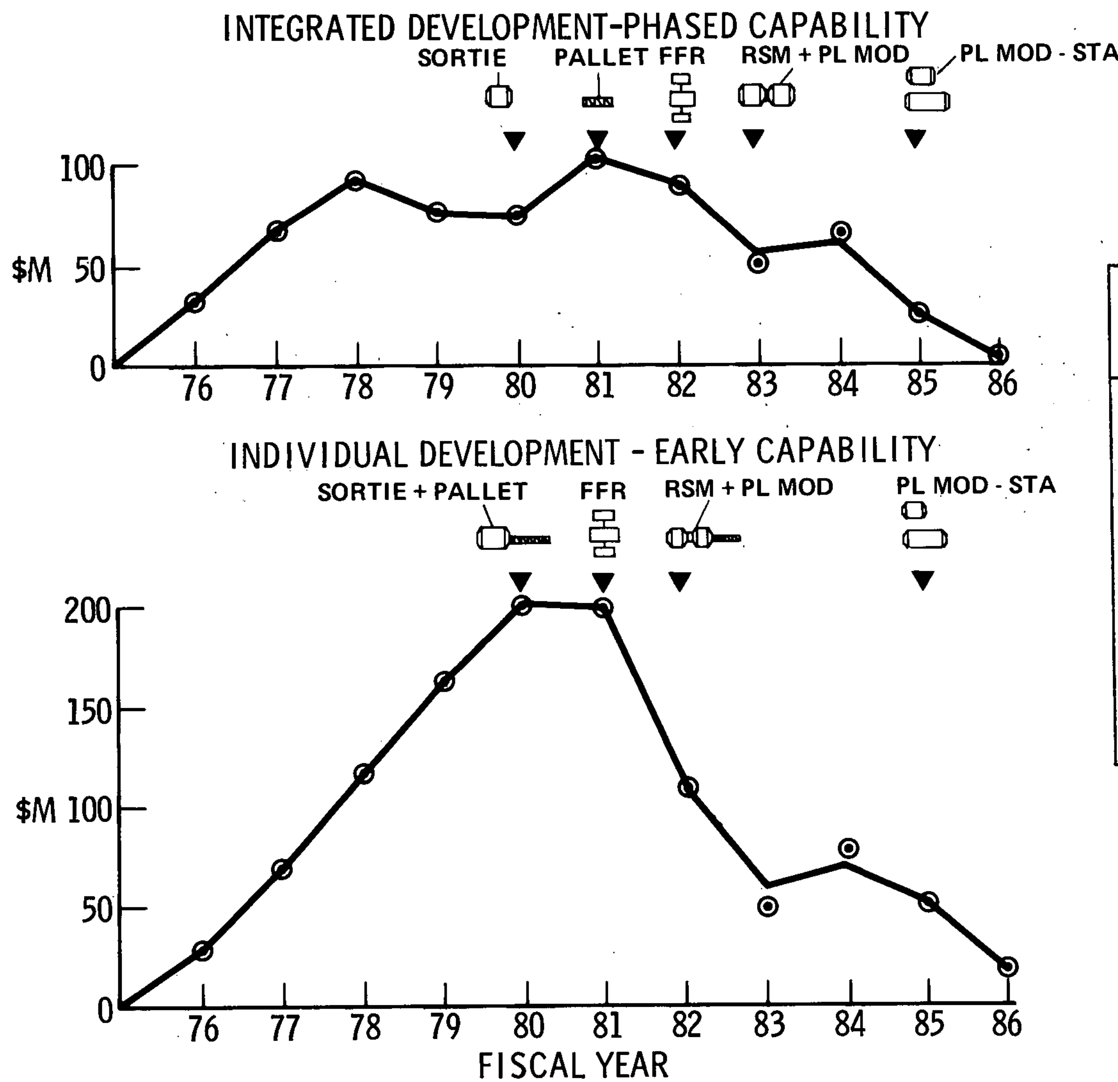
72-1729

LOW EARLY-YEAR FUNDING

The advantages of an integrated phased approach to minimize low early-year funding requirements is graphically shown in the facing chart. The funding shown is for only module development and production – the principal RAM project costs contributing to early-year funding. The upper funding chart represents an integrated evolutionary phased development while the lower chart represents a program where the RAM elements are independently developed due to a compressed availability requirement.

As may be seen, the schedule of the lower chart dramatically increases funding requirements in early years of the RAM project. Delaying the development of the RSM and free-flying RAM by one year from the dates shown on the lower chart to the dates on the upper chart allow these elements to take advantage of applicable development on the sortie RAM and thus reduce the peak funding requirements by 50% and the total RAM family development by approximately 50%.

LOW EARLY-YEAR FUNDING
Development & Production Funds Only



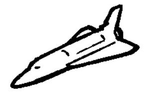
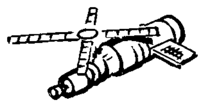
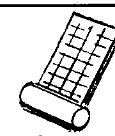
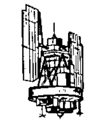
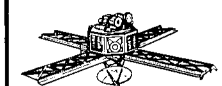
RESULTS OF INTEGRATED DEVELOPMENT
LOW EARLY-YEAR FUNDING TOTAL COST 50% REDUCTION PEAK FUNDING 50% REDUCTION SCHEDULE DELAY REQ RSM & FFR = 1 YR.

72-1752

COMMONALITY – INTERPROJECT

It is essential to achieve maximum use of common and developed hardware if development and production costs are to be held to a minimum. The RAM project has identified many shuttle orbiter components that are compatible with RAM requirements, based upon the orbiter definition as of this date. This includes items such as the fuel cells, reactant storage tanks, nitrogen storage tanks, EC/LS and thermal control system components, etc. Candidate components from other active space programs such as Apollo and Skylab and appropriate military programs have also been identified as shown on the chart.

COMMONALITY — INTERPROJECT

SUBSYSTEM	 SHUTTLE	 SKYLAB	 SKYLAB/CSM	 APOLLO	 USAF/HUGHES	 ERTS	 USAF/MARINER
STRUCTURE	DOCK I/F ADAPTER & MECH.						
EC/LS	MAJOR COMPONENTS						
GN&C	STAR-TRACKER	CMG					
EPS	FUEL CELL REACT. TANKS INVERTERS	REGULATOR Ni-Cd BATTERIES	Ag-Zn BATTERIES	INVERTERS	SOLAR ARRAYS		
COMM/DATA	COMPUTERS	VHF REC. & RANGE UNIT				S-BAND TRANS-PONDER	
CONTROL & DISPLAY	CRTs KEYBOARD TV CAMERA						
PROPULSION							TANKS

72-1757

COMMONALITY – INTRAPROJECT

A primary objective in the preliminary design of the RAM elements has been to minimize development and production costs. To achieve this end, a high degree of commonality was maintained between the sortie RAM, RSM, and payload modules. The pressurized structural shell is identical for the three modules. The sortie RAM and the RSM also use identical subsystem components. Since the RSM or Space Station provides the basic subsystem resources, many components listed are not required for the payload module. Because the free-flying RAMs have different requirements, the opportunities for commonality are somewhat limited. The primary differences between the sortie RAM and the free-flying RAM that affect commonality are: (1) diameter of the primary structure (14 feet versus 12 feet), (2) mission duration (seven days versus five years), and (3) free-flying RAMs are unmanned except for periodic servicing.

COMMONALITY – INTRAPROJECT

	SORTIE RAM	RSM	P/L MOD.	FREE-FLYING RAM
STRUCTURE				
PRESSURE SHELL, I/F ADAPTER	X	X	X	12-FT. DIA.
ELECTRICAL POWER SYSTEM				
FUEL CELL & REACTANT STORAGE	X	X	NA	NA
CONDITIONING & DISTRIBUTION	X	X	X	PARTIAL
CONTROL & DISPLAY CONSOLE	X	X	NA	NA
THERMAL CONTROL SYSTEM				
9-FT. RADIATOR PANELS	X	X	X	12-FT. DIA.
BASIC SYSTEM COMPONENTS	X	X	NA	X
ENVIRONMENTAL CONTROL/LIFE SUPPORT				
ATMOSPHERE STORAGE	X	X	NA	X
PRESS. CONTR., H_2O MGMT.	X	X	NA	NA
ATMOSPHERE REVITALIZATION	X	X	PARTIAL	NA
DATA MANAGEMENT SYSTEM				
COMPUTER COMPONENTS	X	X	NA	X
MULTIPLEX SYS. COMP., SOFTWARE	X	X	X	X
DIGITAL RECORDERS	X	X	ANALOG	BUFFER STORAGE

72-1743

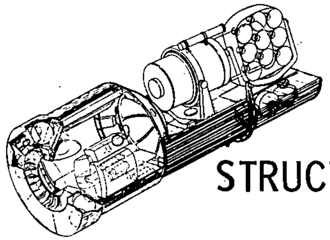
COMMONALITY – RAM & SPACE STATION

Previous charts have shown that RAM has used subsystems not only from other on-going space system programs but has used common subsystems to a great extent in each element. In addition, since RAM will be preceding the Space Station in its development phase, there will be many subsystems developed for RAM that will have potential application in the Space Station and thus minimize its development cost. Candidate subsystems are shown on the facing chart including the RAM elements in which they will be used.

The basic structure for all pressurized RAMs and the interface adapter can be used on the station. Control moment gyros, gimbals, and fixed-head star trackers from the astronomy sortie missions have potential application, as well as components from the controls and displays and data management subsystems.

Free-flying RAM subsystem components as indicated on the chart also will have potential application on the station.

COMMONALITY – RAM & SPACE STATION
Future Subsystem Implementation

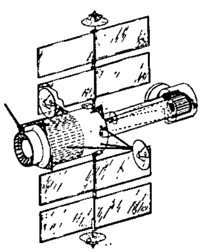


STRUCTURE
- PRESSURE SHELL, I/F ADAPTER & ATTACHMENTS

GN&C
- CONTROL MOMENT GYROS
- WIDE -NARROW ANGLE, SUB ARC-SEC. POINTING
- FIXED-HEAD STAR TRACKERS

CONTROL & DISPLAY
- CRTS, SYMBOL GENERATOR
- KEYBOARD

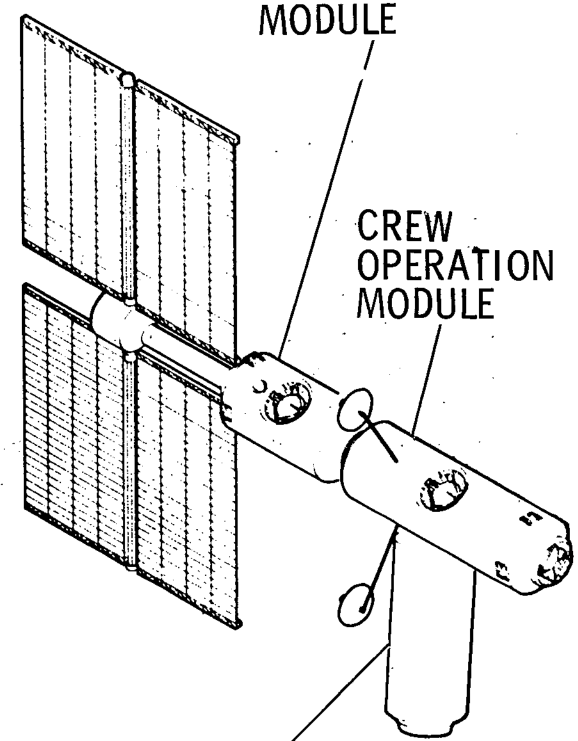
DATA MANAGEMENT
- SMALL DISTRIBUTED COMPUTERS
- TAPE RECORDER



GN&C
- FIXED-HEAD STAR TRACKERS
- MAGNETIC TORQUING

COMM. KU-BAND
- ANTENNAS & TRACKING SYSTEM
- TWTS
- EXCITERS

RCS
- PROPELLANT SYSTEM



SPACE STATION

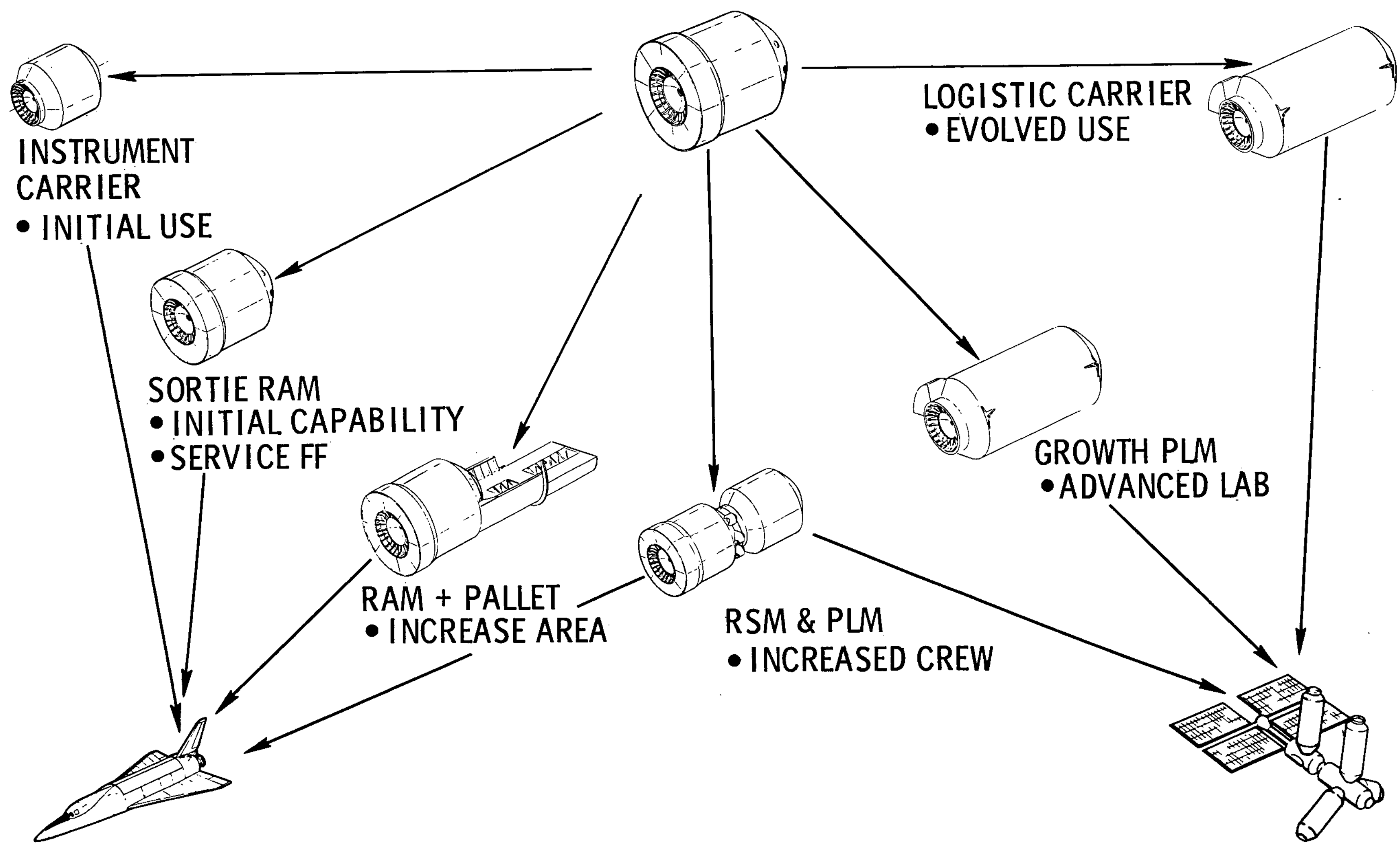
72-1779

RAM VERSATILITY

Use of commonality of structural components and support subsystems to minimize program costs and to provide for evolutionary development and flexibility of RAM modules to meet program requirements is illustrated on this chart. Development may initially progress from the very austere flight instrumentation can to a slightly more advanced sortie RAM by providing additional subsystems over that supplied by the shuttle orbiter, displays and controls, and work stations for two experiment specialists. This sortie RAM can also be used for man-tending free flyers, by including appropriat checkout equipment and necessary logistics.

The sortie RAM can be adapted to an RSM by the addition of subsystems and habitability provisions and may be used as a 10-foot sidewall payload module with the integration of payload equipment. The addition of standard sections extends the 10-foot payload module to any desired length for use with sortie missions, or in the Space Station mode as an advanced lab, or potentially a logistics carrier.

RAM VERSATILITY



72-1733

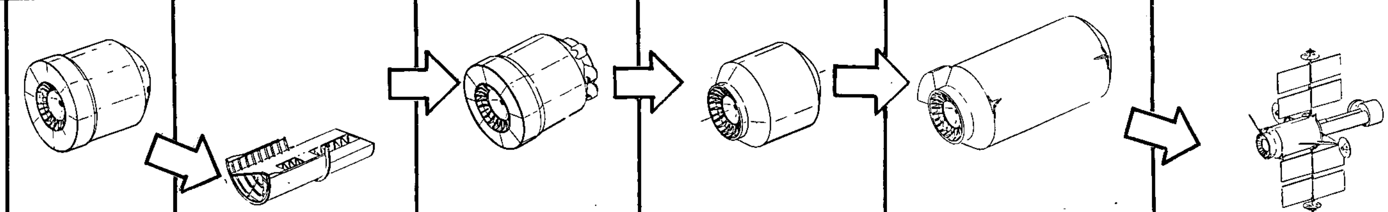
RAM CAPABILITY EVOLUTION SUMMARY

The overall RAM evolution from early to advanced capabilities is shown on the chart, along with the application of capability and estimated costs, of each step in this evolution.

Evolution begins with the sortie RAM, which provides initial capabilities and returns from each of the disciplinary areas. Addition of a pallet as a new element requires a modest investment with significant increase in capability for viewing experiments, providing the RSM can significantly increase the returns per mission. Use of payload modules decreases unit cost, with DDT&E costs required for adaptation from sortie RAM, and in the larger 24-foot sidewall length used with the Space Station, provides a very significant increase in capability necessary to house the larger advanced station labs.

Addition of the free-flying RAM is accomplished at any point in this evolution, since it is an additional element with commonality existing only at the subsystem or lower levels.

RAM CAPABILITY EVOLUTION SUMMARY



RAM	SORTIE RAM	PALLET	RAM SUPPT. MODULE	PAYLOAD MODULE	PAYLOAD MOD (STA.)	FREE-FLYING RAM
EVOLUTION FROM SORTIE RAM REQUIRED TO INCREASE CAPABILITY FROM SORTIE RAM	BASIC	NEW ELEMENT	ADD CREW HABIT.	DELETE SUBSYSTEMS	INCR. LENGTH	NEW ELEMENT
PAYLOAD USE OF INCREASED CAPABILITY	INITIAL LABS.	ADDITIONAL SENSORS & EQPT.	2-SHIFT OPER.	ADDITIONAL LAB. EQPT.	ADVANCED LABS. -COMPL.	LARGE OBSERVATORIES
ASTRONOMY	✓	✓				✓
PHYSICS	✓		✓	✓	✓	
EARTH OBS	✓	✓	✓		✓	
COMM NAV	✓	✓	✓		✓	
MTL SCI. MFG.	✓		✓	✓	✓	
TECHNOLOGY	✓	✓	✓			
LIFE SCIENCES	✓		✓		✓	
INTEG. DDT&E COST $M	193 BASIC	+ 11	+ 43	+ 10	+ 32	+ 128
CUM. INTEG. DDT&E $M	193	204	247	257	289	417
UNIT COST $M	23	1.2	24	6	11	23

72-1734

APPLICATION OF STUDY RESULTS

The RAM Study has produced data and analyses believed to be of direct usefulness to NASA efforts, in addition to providing the data bank necessary for entering the RAM design and development phase.

Other applications of this data are believed to exist in the Space Shuttle design, sortie can definitions, experiment facilities definitions, and LST studies, as discussed in later pages.

The ongoing studies scheduled for completion before 12 August 1972, will produce results applicable to LST Studies, RAM/Sortie Can/Shuttle design, and RAM subsystems. The RAM subsystem analyses currently being conducted by European members of the Convair Aerospace RAM team are considered of particular interest and importance in bringing an international viewpoint to the solutions and implementation of some of the more critical subsystem areas.

During the study, certain areas were discovered to be potentially quite complex and important to efficient development and use of RAM. The first of these concerns the verification of the RAM/orbiter combination to accomplish the missions. The second concerns the area of detailed user interfaces with RAM in areas of payload checkout and preparation.

APPLICATION OF STUDY RESULTS

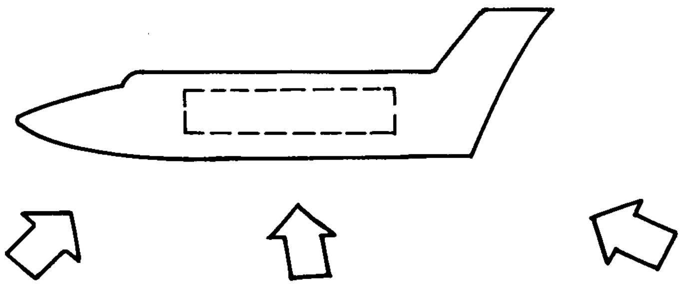
- DATA BANK FOR RAM DESIGN & DEVELOPMENT
  - PRELIMINARY DESIGNS
  - CEI SPECIFICATIONS
  - PROJECT DEVELOPMENT PLAN
- STUDY RESULTS APPLICABLE TO OTHER NASA EFFORTS
  - SPACE SHUTTLE
  - SORTIE CAN
  - EXPERIMENT FACILITY DEFINITIONS
  - LARGE SPACE TELESCOPE (LST)
- CONTINUING RAM PHASE B STUDY TASKS – COMPLETION BEFORE 12 AUGUST 1972
  - ANALYSIS OF APPLICATION OF COMPOSITE STRUCTURES TO LST
  - RAM DEPLOYMENT MECHANISM CONCEPT
  - EUROPEAN PARTICIPANTS – SUBSYSTEM ANALYSIS
- RECOMMENDED FURTHER STUDY AREAS
  - RAM/ORBITER INTERFACE VERIFICATION
  - USER GROUND OPERATIONS

72-1813

Definition of RAM as a shuttle payload required in-depth study of shuttle characteristics, particularly for the sortie mission and the free-flying RAM service mission. These studies permitted the definitions of RAM as a viable and real shuttle payload that recognizes both the capabilities and constraints of the interface with the shuttle system. These RAM definitions then, are believed useful to shuttle design studies in that they represent a set of thoroughly defined representative shuttle payloads that have been designed to be compatible with the shuttle, and yet fulfill the requirements of the RAM project.

Particularly sensitive interface areas have been quite thoroughly investigated and recommendations made to NASA in these areas. The results of various analyses should be of particular interest, such as the preli minary determination of revisions to the shuttle system expected to permit increase of on-orbit stay time to 30 days.

RESULTS APPLICABLE TO SPACE SHUTTLE



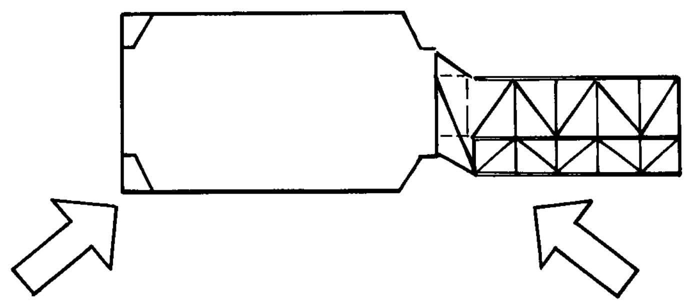
DEFINITION OF SHUTTLE PAYLOADS • CHARACTERISTICS • INTERFACE VISIBILITY	IDENTIFICATION OF PARTICULARLY SENSITIVE AREAS	SHUTTLE CHARACTERISTICS ANALYSES OF INTEREST TO PAYLOADS
1. PHYSICAL – WT. ENVELOPE, ATTACH, CG	MULTIPLE PAYLOAD ATTACH. CG FLEXIBILITY	MULTIPLE-PAYLOAD ATTACH.
2. ENVIRONMENTAL – ATMOS., ACOUSTIC, THERMAL	ATMOSPHERIC CONTAMINATION (RCS PROPELLANT DUMPS)	ENVIRONMENTAL PREDICTIONS
3. PERFORMANCE – ORBIT, CREW, RESOURCES POINTING AND STABILITY	POLAR-ORBIT CAPABILITY $I_{Min.}$, STABILITY RATES	SHUTTLE SYSTEM REQT. FOR 30-DAY MISSIONS STABILIZING METHODS & REQT.
4. FUNCTIONAL – MISSIONS, PROFILES, OPERATIONS, DELIVERY, RETRIEVAL, GROUND & DATA NETS	CREW PROVISIONS LAUNCH & ENTRY COMM. PROVISIONS	COMM/DATA – CAPABILITY TO USE TDRS & MSFN NETS CREW SURVIVAL REQT.

72-1764

RAM STUDY RESULTS APPLICABLE TO SORTIE CAN

A significant portion of RAM design and operations analyses are considered directly applicable to Sortie Can studies. These results include the definitions and requirements of the representative sortie mission payloads, detailed mission and operations analyses, design studies, and development cost and schedule data. Definition of shuttle interfaces accomplished for RAM sortie missions should also be directly useful to Sortie Can definition studies.

RAM STUDY RESULTS APPLICABLE TO SORTIE CAN



PAYLOAD DATA	MISSION & OPER. DATA	DESIGN DATA	TRADES & ANALYSES	DEVELOPMENT DATA
DEFINITIONS & REQT. OF 35 TYPICAL SORTIE MISSION PAYLOADS: • EXPER. IDENTITY • WT. ENVELOPE • RESOURCE REQT.	DETAIL PROFILES, TIMELINES & FUNCTIONAL REQT.: • SORTIE • FF SERVICE GSE REQUIREMENTS SHUTTLE INTERFACES	CONFIGURATION DESIGNS PAYLOAD INTEGRATION, DESIGNS SUBSYSTEM DEFINITIONS REDUNDANCY REQT. & OPTIM. SAFETY REQT. COMMONALITY CANDIDATES	SUBSYSTEM OPTIONS SIZING STABILIZATION DATA HANDLING CONCEPT - MAG. TAPE INTEGRATED C&D FUEL CELL POWER SOURCE PRODUCIBILITY	TEST PLAN SCHEDULES COST DATA REQT. VERIFI-CATION

72-1765R

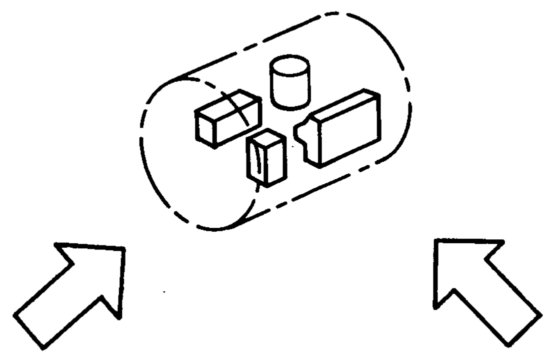
RAM STUDY RESULTS APPLICABLE TO EXPERIMENT FACILITY DEFINITION

RAM study results include definition of the characteristics, capabilities, and payload-to-RAM interfaces for a representative set of payloads, that should be considered in the final definition of the actual RAM payloads. Typical equipment necessary for integrations of these payloads, expected environments, and countermeasures to provide compatability with the environment have been defined in detail.

Analysis and simulations of typical crew and mission operations provide data for consideration of these factors in experiment design.

Special analyses that will provide data for definition of payloads to match particular accommodation and mission modes are also provided.

RAM STUDY RESULTS APPLICABLE TO EXPERIMENT FACILITY DEFINITIONS



DEFINITIONS

- PAYLOAD CARRIERS-INTERFACES, CAPABILITIES & CHARACTERISTICS
- TYPICAL INTEGRATION EQUIPMENT
- ENVIRONMENT
- COUNTERMEASURE REQUIREMENTS
- EXPERIMENT CREW ACTIVITIES & TIMELINES
- MISSION PROFILES & OPERATIONS
- FURTHER DEFINITION OF SOME EXPERIMENTS

  SIZE - WT. - RESOURCES - OPERATIONS

ANALYSES & DATA

- ACCOMMODATION MODE
  ATTACHED - FREE FLYING
  SORTIE - STATION
- SELECTIONS OF EARLY REPRESENTATIVE GROUPS OF EXPERIMENTS
- ASSESSMENT OF EFFECTS OF PROGRAMMATIC VARIATIONS ON PAYLOADS
- USE OF NON-STATION ORBITS
- SIMULATIONS OF EXPERIMENT MISSIONS & OPERATIONS

72-1771

RAM STUDY RESULTS APPLICABLE TO LARGE SPACE TELESCOPE (LST)

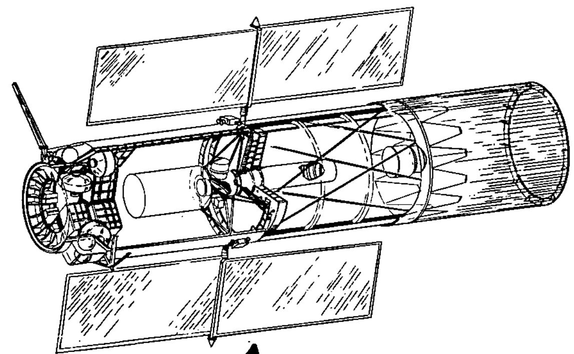
Studies of free-flying RAM, and accommodation of LST Advanced Stellar Astronomy, provide definition of operations based on recent LST payload definition. While the LST definition may be revised, much of the analyses and data should still apply.

The definition of LST is based on Titan III launch and MSFN-only data support (LST ground rules) with an alternative design for a shuttle-launched, TDRS data supported configuration. This LST design includes certain features as listed opposite that can be considered for potential incorporation into LST.

RAM definition includes detailed description and requirements of the shuttle service missions to the free-flying LST, as well as detailed analyses of environmental contamination, and of exposure to natural trapped radiation for various orbits. The latter analyses provides the basis for recommendation of a 325-n.mi. operating orbit in lieu of the ground-ruled 400-n.mi. orbit. Several of the ongoing study efforts will provide additional results applicable to LST:

1. Analysis of the potential application of composite materials (graphite/epoxy) to major stuctural elements of the telescope.
2. Analysis of solar arrays by MBB.
3. Analysis of image motion compensation by SAAB-Scania.
4. Analysis of thermal control by ERNO. These are discussed in subsequent charts.

RAM STUDY RESULTS APPLICABLE TO LARGE SPACE TELESCOPE (LST)



FEATURES

- GRAVITY GRADIENT MOMENTUM EXCHANGE
- DATA RECORDING TO MAXIMIZE OBSERVATIONS USING MSFN (BEFORE TDRS).
- ALTERNATIVE METHOD FOR BRIGHTNESS DYNAMIC RANGE ENHANCEMENT
- OPTION FOR BODY-POINTING STABILIZATION TO 0.005 ARC-SEC.
- FOR TITAN III LAUNCH – SELF-CIRCULARIZING FROM ELLIPTICAL ORBIT

DEFINITIONS

- SHUTTLE SERVICE MISSION – PROFILE & OPERATIONS RELIABILITY & MAINT REQT. LST REQUIREMENTS SERVICE MODULE DEFINITION
- OBSERVATION PROGRAM
- ALTERNATIVE DESIGN FOR SHUTTLE LAUNCH
- ALTERNATIVE DESIGN FOR TDRS
- MSFN REQUIREMENTS TO MODIFY TO 5 MBPS

DATA BANK

- MISSION & OPERATIONS, SUBSYSTEM DESIGN
- DATA ON APPLICATION OF COMPOSITE MATERIALS TO TELESCOPE STRUCTURE
- RADIATION EXPOSURE ANALYSIS FOR ORBIT RECOMMENDATION
- CREDIBLE WEIGHT & MASS PROPERTIES DATA
- DEVELOPMENT SCHEDULE & COST DATA

72-1772 R

RAM STUDY – CONTINUING ACTIVITIES

For Completion Before 12 August 1972

Several study tasks are currently in work which are scheduled for completion before 12 August 1972, as listed on the opposite chart.

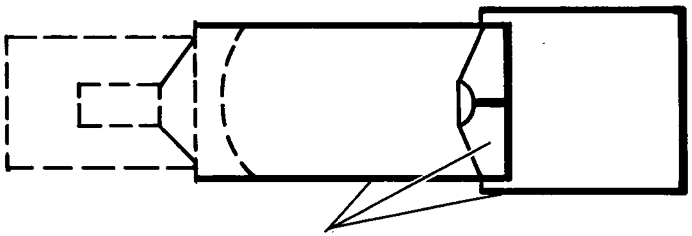
Analysis of potential application of composite materials to major structural elements of the large space telescope is being accomplished to provide data to NASA bearing on a choice of materials for this use. Design studies are based on use of graphite/epoxy materials as a potential replacement of elements currently designed for Invar and titanium, with the primary advantages forecast being reduced weight and greater allowable thermal tolerances.

Design studies are under way to device concepts for deployment of RAM clear of the cargo bay while retaining pressurizable, manned access to the deployed RAM from the orbiter cabin and/or airlock.

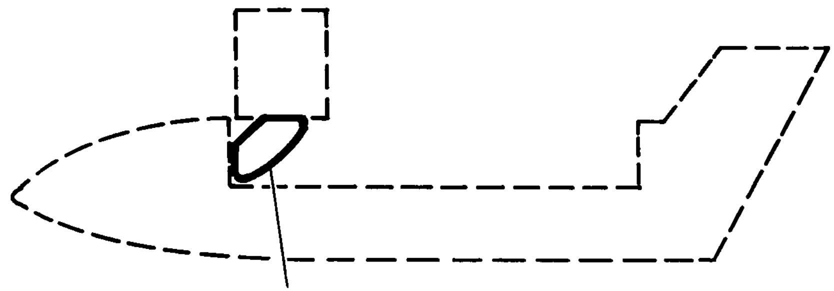
European participants in the RAM study efforts are currently performing analyses of particular subsystems areas as listed on the facing charts. These tasks were initiated by technical teams from each of these companies working at the San Diego Operation for about a one-month period. The work will be completed at the team members' home plants in Europe, and results delivered to the NASA before 12 August 1972.

RAM STUDY — CONTINUING ACTIVITIES
For Completion Before 12 August 1972

- COMPOSITE STRUCTURE ANALYSIS FOR LST CONSIDERATION



- DEPLOYMENT MECHANISM CONCEPT



- EUROPEAN PARTICIPANTS - SUBSYSTEM ANALYSES

COMPANY	COUNTRY	STUDY TASK
ERNO	W. GERMANY	ELECTRICAL POWER, THERMAL CONTROL
MBB	W. GERMANY	SOLAR ARRAYS
SAAB-SCANIA	SWEDEN	DATA PROCESSING (IMC) COMPUTER TRADE PHASED ARRAYS

72-1741

RECOMMENDED FUTURE RAM STUDY AREAS

Two areas where additional study before the initiation of RAM Phase C/D would provide increased efficiency in development and operational usage are:

1. RAM/Orbiter Interface Verification – Analysis of the development flight requirements of RAM, and interlacing them into planned shuttle development to ensure overall operational compatibility and capability before full RAM operations, with minimum funds and schedule requirements.
2. User Ground Operations Analysis – Analysis of the considerable diversity of ground activities potentially required by the many users of RAM, to verify, or provide for, the special needs of particular users.

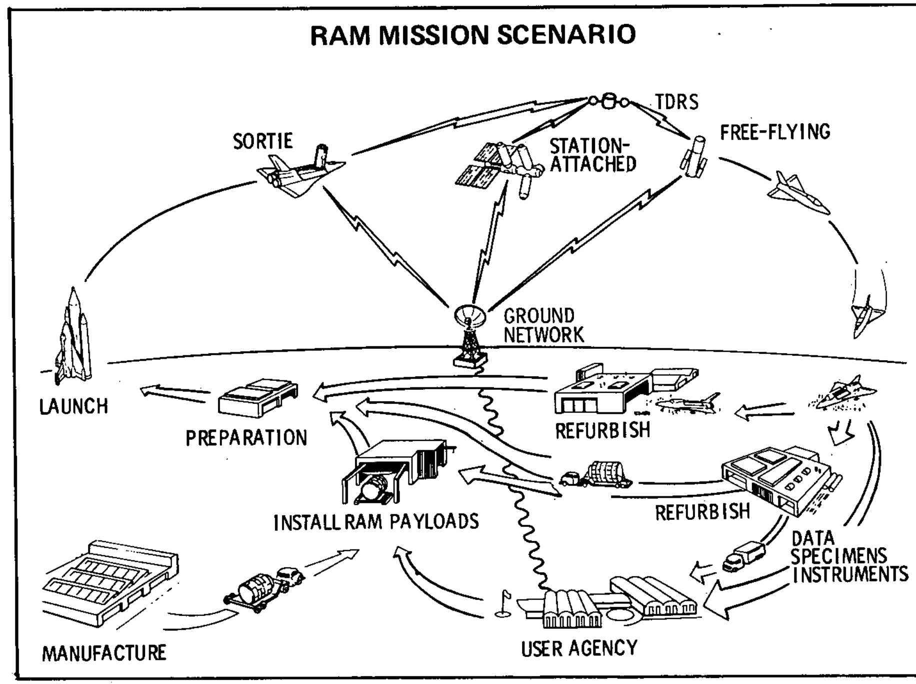
The following charts describe these areas.

RECOMMENDED FUTURE RAM STUDY AREAS

- RAM/ORBITER INTERFACE VERIFICATION

  - ENVIRONMENTAL
  - INTERACTIONS
  - RAM QUALIFICATION

- USER GROUND OPERATIONS ANALYSIS
  - DETAILED INTERFACES
  - CONSIDERATION OF LOCATIONS



72-1742

RECOMMENDED STUDY AREA – RAM/ORBITER INTERFACE VERIFICATION

The overall purpose of this recommended study area is to plan the development flight phase of RAM to verify the RAM/orbiter interfaces, and concurrently verify RAM capabilities. The intent is to investigate means to accomplish this during the scheduled development flights of the orbiter with the goal of no additional flights required for RAM development. This should provide the most efficient means to achieve RAM capability to support applications and research efforts.

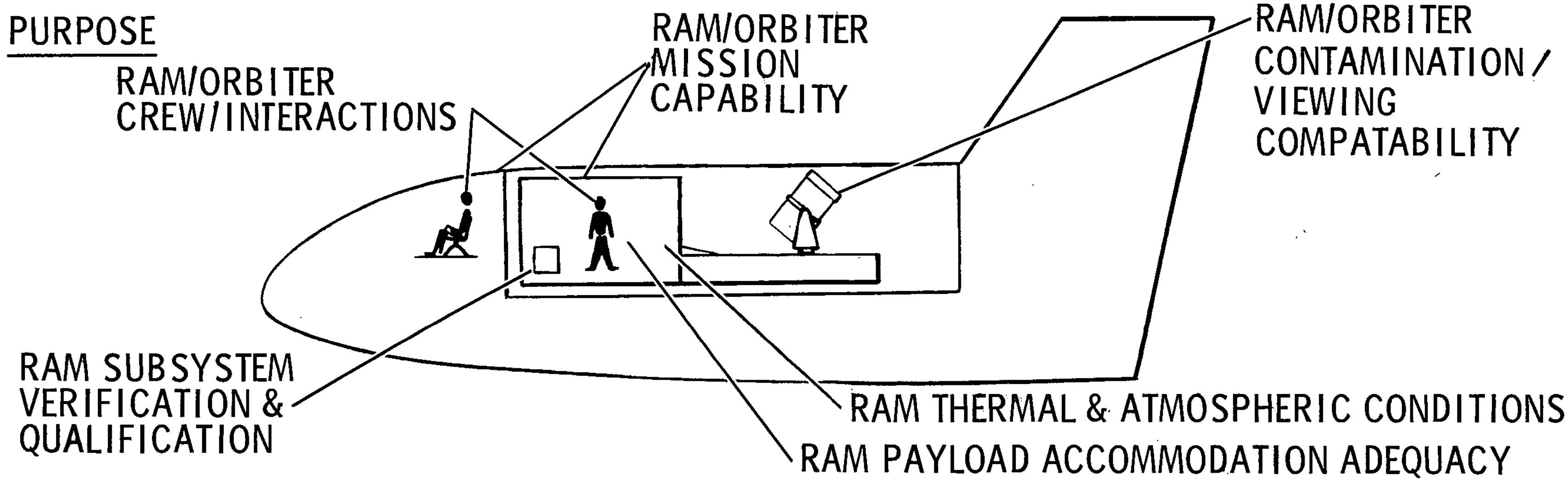
Examples of the areas to be verified during this development phase are shown on the facing chart. Also shown is an example of how this may be accomplished during orbiter development. Verification of RAM physical and configuration compatability could potentially be accomplished during orbiter horizontal flight program. This might include checks of attach points, electrical and plumbing interconnects, and general fit of RAM into the cargo bay.

During the first ten flights before orbiter IOC (as currently envisioned) opportunities appear to exist for on-orbit verification of RAM interfaces and RAM mission capability.

Study of these possibilities for RAM verification should lead to the most efficient development of RAM.

RECOMMENDED STUDY AREA –
RAM/ORBITER VERIFICATION

PURPOSE



POTENTIAL INTEGRATION

EXAMPLE COMBINED RAM/ORBITER DEVELOPMENT

ORBITER FLIGHTS	RAM POTENTIAL	SCHEDULE			
		76	77	78	79
HORIZONTAL	PHYSICAL & CONFIGURATION				
ORBITAL FIRST TEN	ENVIRONMENTAL PERFORMANCE MISSION CAPABILITY				

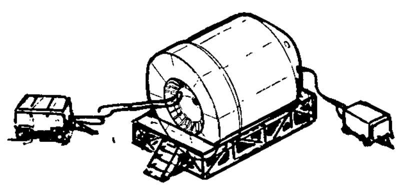
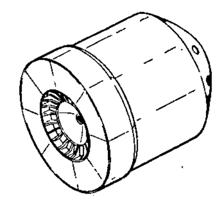
72-1816

RECOMMENDED STUDY AREA – USER GROUND OPERATIONS

The example shown opposite shows the possible areas where the specific needs of a user during his ground operations may affect the detailed design of connections and interfaces, or possibly affect the RAM assembly sequence. Some additional design requirements may be also uncovered, such as the examples of operating life, and wear protection.

The recommended study effort should address the specific needs and potential ground operations of a representative spectrum of users. Determination of RAM detail design requirements should evolve from this analysis, and lead to more efficient user operations.

RECOMMENDED STUDY AREA – USER GROUND OPERATIONS – EXAMPLE

USER OPERATION	RAM DESIGN
	
INSTALLATION OF PAYLOAD HOLDING FIXTURE LARGE SIZE EQUIPMENT	EQPT. MOUNTING PROVISION FLEXIBILITY ATTACH POINTS TO FIXTURE ASSEMBLY SEQUENCE - 102 RING & EFFECT ON JOINT & SEAL DESIGN
PAYLOAD CHECKOUT	INTERFACE CONNECTIONS TO GROUND POWER, AIR, ETC. COMPONENT OPERATING LIFE REQT. WEAR PROTECTION REQT.
SHIPPING & STORAGE	CONTAINER ATTACH REQT. ENVIRONMENTAL PROTECTION REQT.

72-1736

RAM PROGRAM IMPLEMENTATION FLEXIBILITY

The RAM elements developed during this study can be combined in a number of ways to create productive programs.

A limited, low-cost program can be generated using the sortie RAM and pallet only. The sortie RAM can accommodate the shuttle flight test instrumentation for both horizontal and orbital flights, and combined with a pallet go on to perform sortie missions, either with payloads combining several disciplines or with dedicated payloads. In addition, this mode of operation can initiate international participation, using either European-built hardware elements and experiments or European experiments installed in American-built RAM system elements.

An expanded program can be performed using the additional RAM family elements. As noted before, such a program can be planned within the constraints of low early-year funding and can take advantage, with proper scheduling of the cost benefits from integrated development. With the addition of the RAM support module and sortie payload module, increased returns can be obtained from sortie missions. Free-flying RAMs provide the advantages of large man-tended observatories. When a Space Station becomes available, the program can take advantage of the long-duration mission times and available supporting resources.

Examples of these two types of programs with a representative experiment plan and their attendant funding requirements are presented in the following charts.

RAM PROGRAM IMPLEMENTATION FLEXIBILITY

SELECTED RAM ELEMENTS PROVIDE VERSATILE PROGRAM OPTIONS

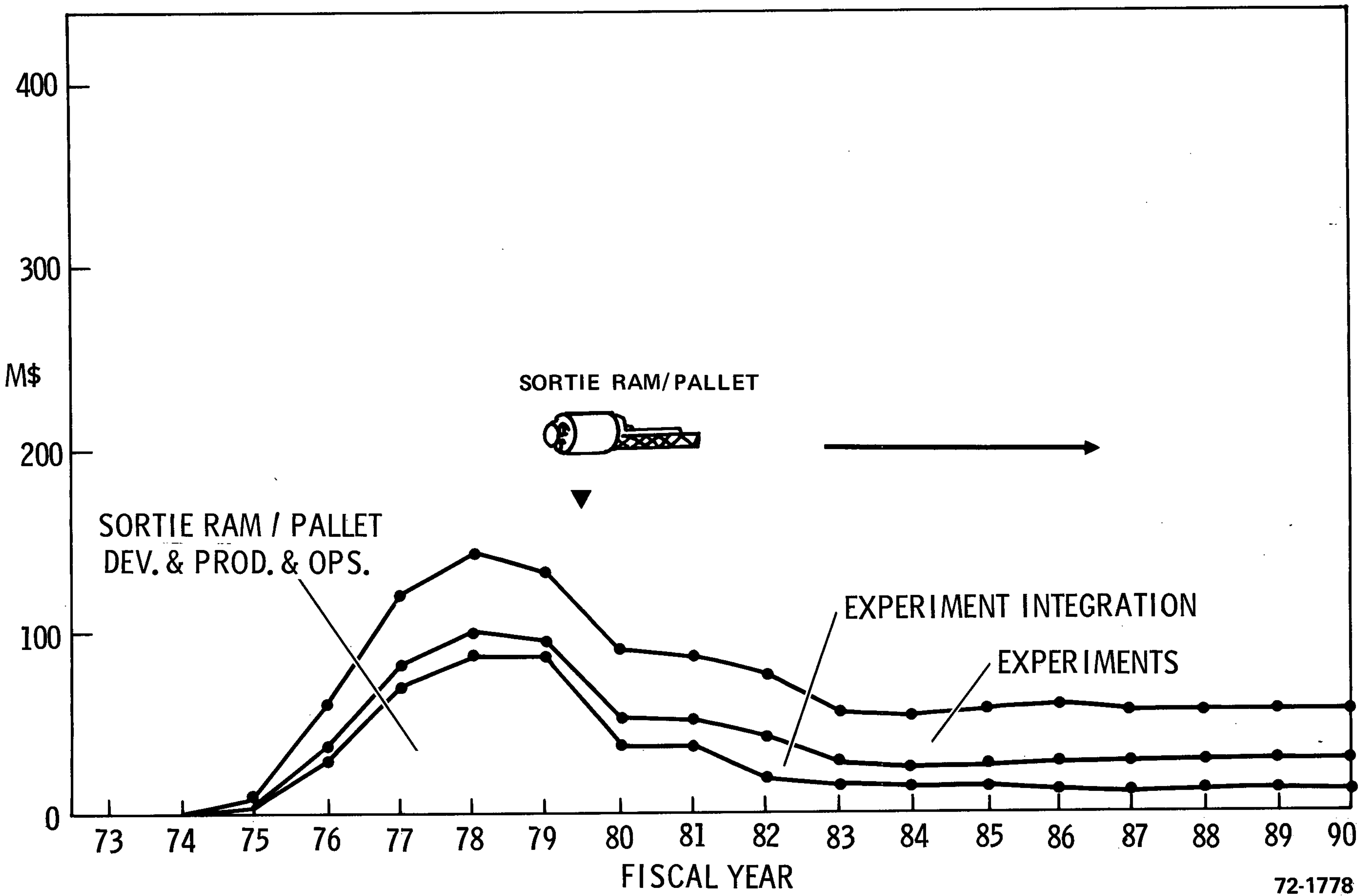
- LIMITED – SORTIE RAM/PALLET ONLY
  - LOW FUNDING LEVEL
  - SHUTTLE FLIGHT TEST INSTRUMENTATION
  - PRODUCTIVE PROGRAM
  - INITIATE INTERNATIONAL PARTICIPATION
- EXPANDED PROGRAM – ADDITIONAL RAM FAMILY ELEMENTS
  - LOW EARLY-YEAR FUNDING
  - COST BENEFIT FROM INTEGRATED DEVELOPMENT
  - INCREASE RETURNS FROM SORTIE MISSION
  - PROVIDE LARGE MAN-TENDED OBSERVATORIES
  - CAPITALIZE ON SPACE STATION MISSION DURATION & RESOURCES

72-1732

SORTIE RAM/PALLET ONLY PROGRAM

The facing chart shows the annual funding requirements for sortie RAM/pallet-only program, with a total of 96 flights. These flights are the same flown for Case C158 encompassing these two RAM elements. The RAM project funds include the sortie RAM and pallet development, production (four sortie RAMs and two pallets), and operations, as well as experiment integration. Experiment funding requirements are shown at the top for reference. As may be seen, peak RAM project funding requirements of approximately $100 million occur in FY 1978 and FY 1979 and drop sharply thereafter. Total program cost through FY 1990 of about $1.2 billion includes $600 million for experiments. Shuttle transportation costs are excluded.

SORTIE RAM/PALLET ONLY PROGRAM



REPRESENTATIVE RAM EXPERIMENT PLAN
Case C158 – $150M Constraint

The experiment plan shown represents a rather well-balanced program employing all mission modes at a total RAM project funding level of $150 million per year. The program shown is to be considered representative – flexibility exists in the selection and sequencing of many RAM payloads.

General features of this program include high-energy, solar and x-ray free-flying RAMs and support of station-attached payloads by the Initial Space Station (ISS) in 1985 and the Growth Space Station (GSS) in 1989. Ohter program features include:

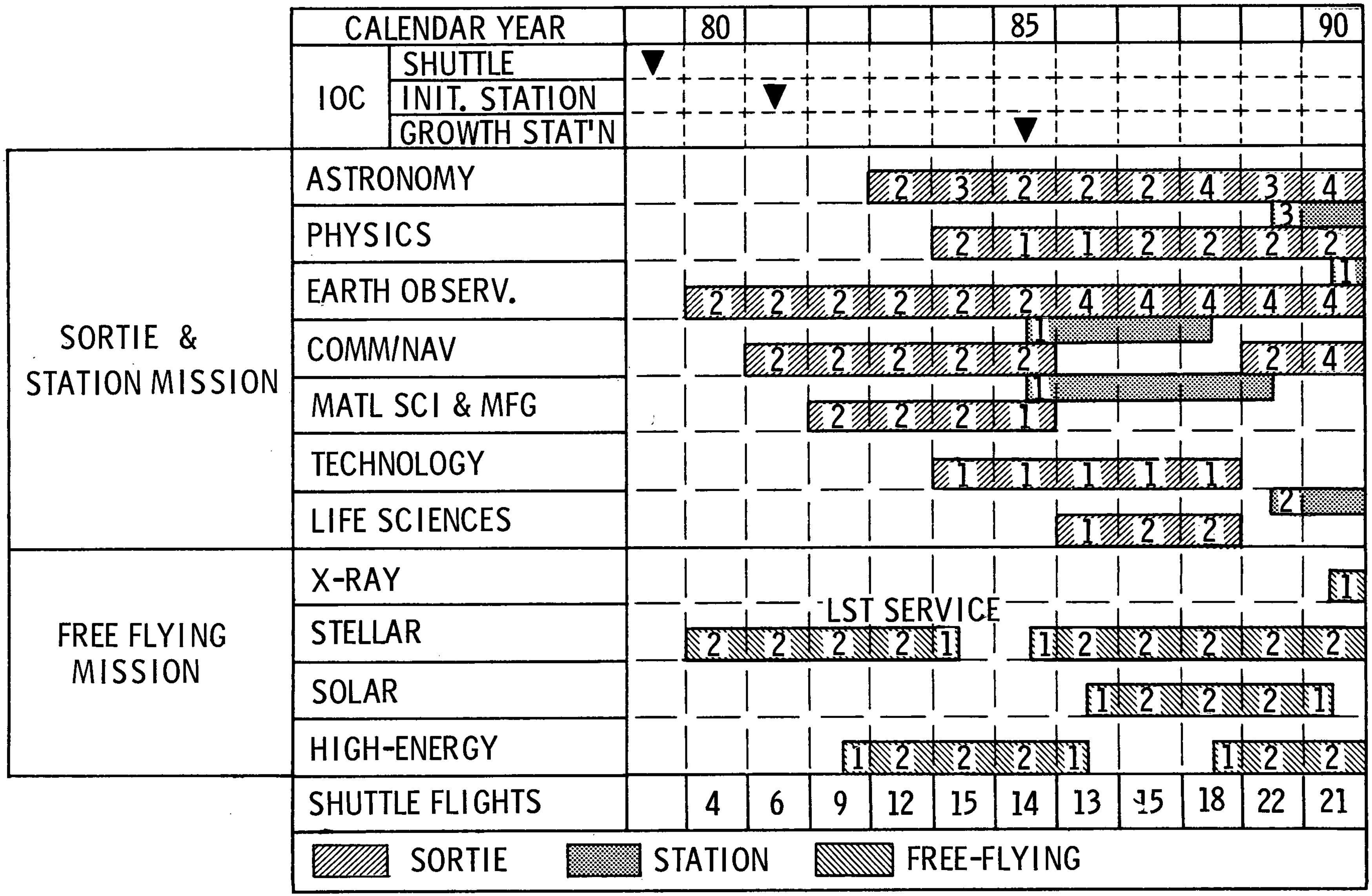
SORTIE – Balanced sortie program at a moderate to heavy flight schedule, including introduction of an RSM for up to six mission and payload specialists plus a shuttle crew of two.

FREE-FLYING RAMS – Funding includes cost of developing and buying the free-flying RAMs and integrating the high-energy, x-ray, and solar payloads. The program accounts for service flights for all free-flying RAMs, including a Titan-launched Large Space Telescope.

STATION-ATTACHED – Station-attached payloads are included for all baseline disciplines and use two RAMs initially built for sortie missions.

It is concluded that an effective experiment program using all mission modes can be accomplished at this funding level.

REPRESENTATIVE RAM EXPERIMENT PLAN
Case C158 — $150 M Constraint



72-1819

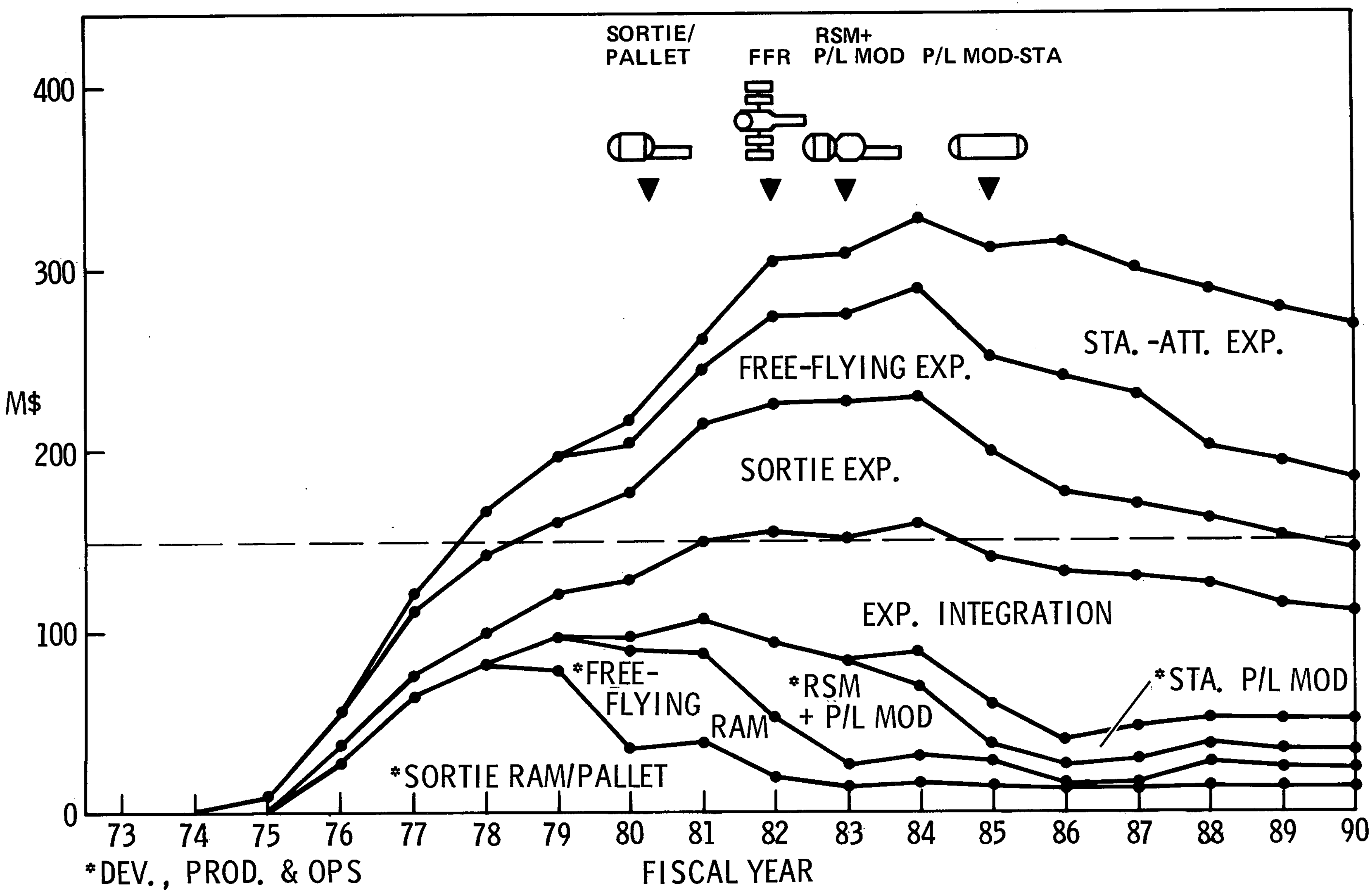
SORTIE + FREE FLYING + STATION ATTACHED

The facing chart shows the annual funding requirements to accomplish the representative experiment plan of program C158, which has a constraint target of $150 million per year for RAM project funding. The RAM project funds include RAM element development, production, and operations, and experiment integration. The latter cost category includes experiment integration, per se, experiment integration interface hardware, and experiment integration testing. In the chart, experiment funding requirements are shown on top of the RAM project for reference and are identified for the three basic mission modes. RAM project hardware costs are shown for each of the RAM major elements, the sortie RAM and pallet, free-flying RAM, RSM and payload modules, and station-attached payload modules.

This program includes sortie RAM becoming available in 1980, the free-flying RAM in 1982, the RSM in 1983, and station-attached module in 1985. Production quantities of these elements are four sortie RAMs, three free-flying RAMs, two RSMs, and ten payload modules. This program includes a total of 133 sortie missions and 16 free-flying RAM deployment and retrieval and station-attached deployment flights.

Total program cost through FY 1990 is about $3.8 billion, of which $2.0 billion is for experiments. Shuttle transportation costs are excluded.

SORTIE + FREE-FLYING + STATION ATTACHED



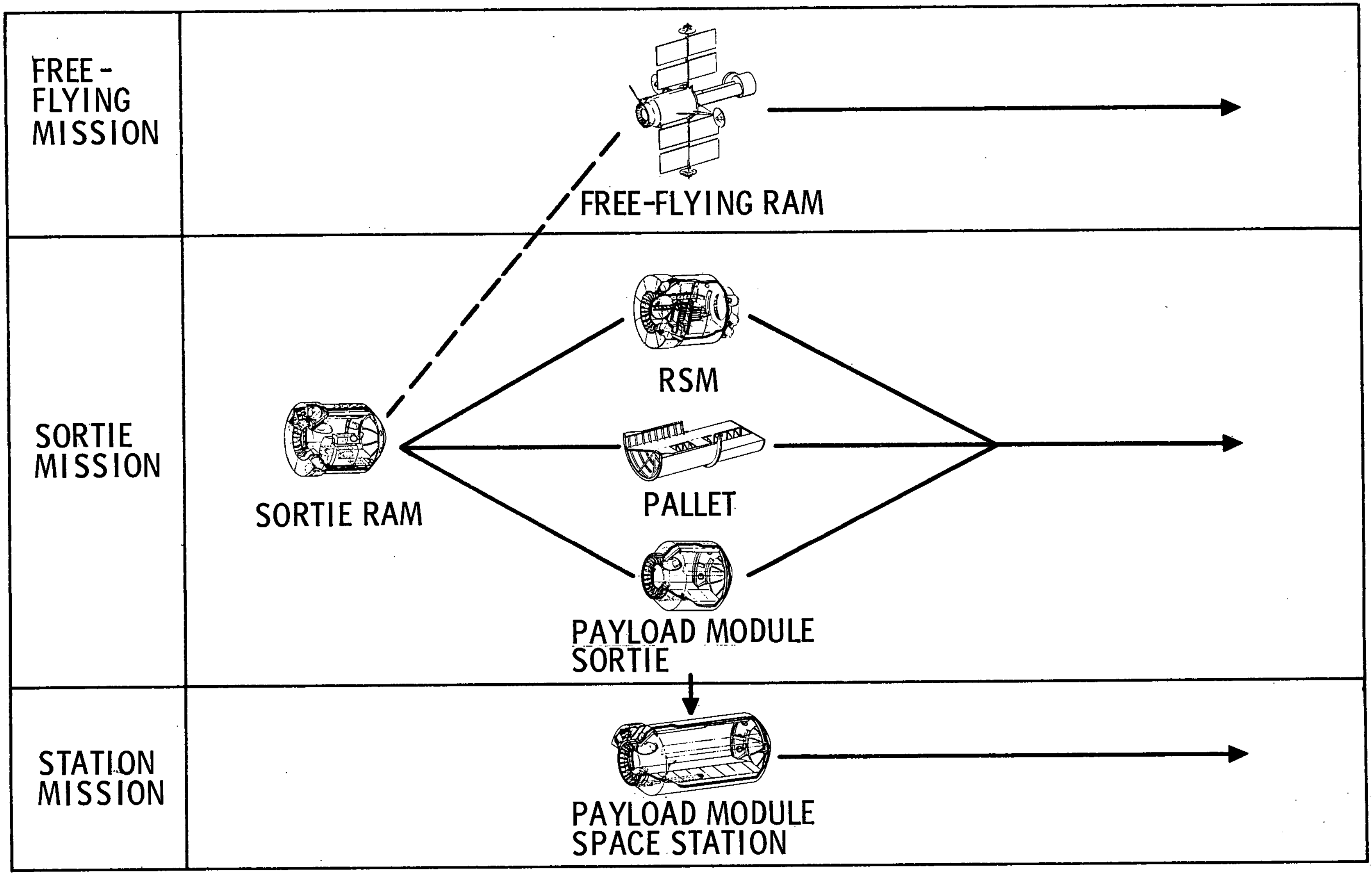
72-1776R

RAM SYSTEM EVOLUTION

Previous charts have shown productive programs that can be accomplished with various combinations of RAM elements and their required funding levels. They have also shown that to minimize development costs, RAM elements should take advantage of an integrated development program. This integrated program requires the sortie RAM to be developed first with other RAMs being developed later on a schedule basis.

Within the requirements of an integrated development schedule, the evolution of the RAM system can be very flexible, depending upon the experiment program goals and the funding available. Following the sortie RAM several options are available for developing the additional required elements. Free-flying RAMs may be developed after or before an RSM and a sortie payload module. Similarly, a pallet may be developed before or after an RSM. The timing of a Space Station has little effect on the development of a free-flying RAM because it can be serviced by the shuttle. If an RSM and sortie payload module are not developed, a station paylooad module can be directly developed from the sortie RAM. An RSM and sortie payload module could be developed after a station payload module with no cost increase, but it is highly unlikely that these modules would be developed after the Space Station is operational, since the station can offer the extended mission duration and increased crew facilities.

RAM SYSTEM EVOLUTION



72-1811

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CONCLUSION

THE SELECTED RESEARCH & APPLICATIONS MODULES WILL PROVIDE ECONOMICAL EXPERIMENT/PAYLOAD ACCOMMODATIONS FOR REALIZATION OF PRACTICAL APPLICATIONS OF SPACE TECHNOLOGY

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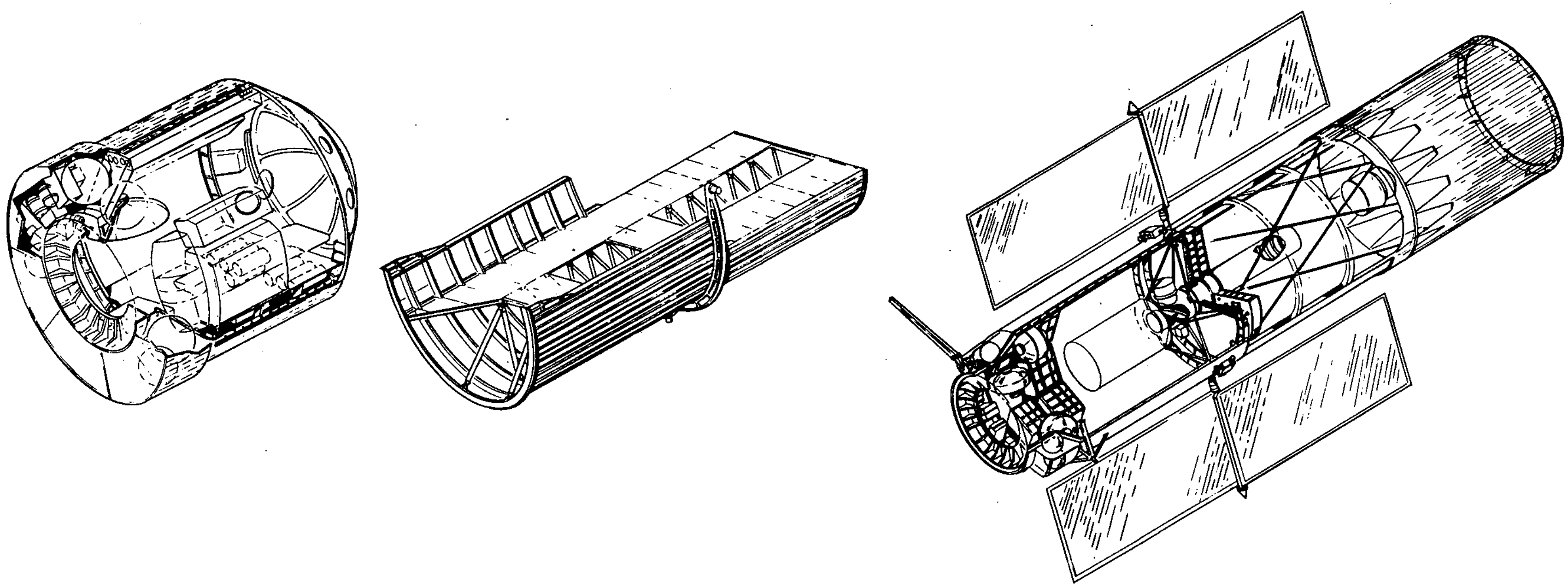
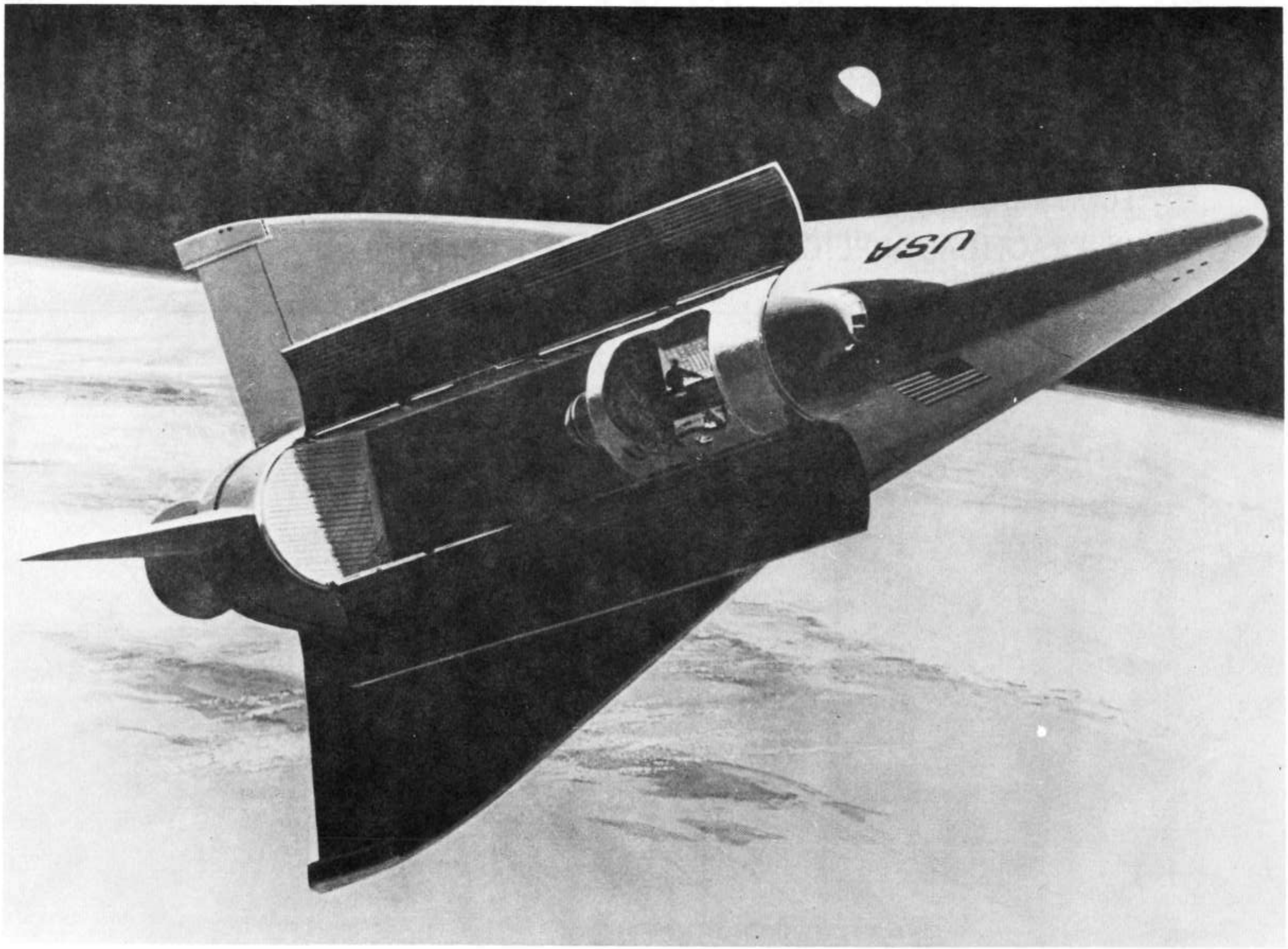
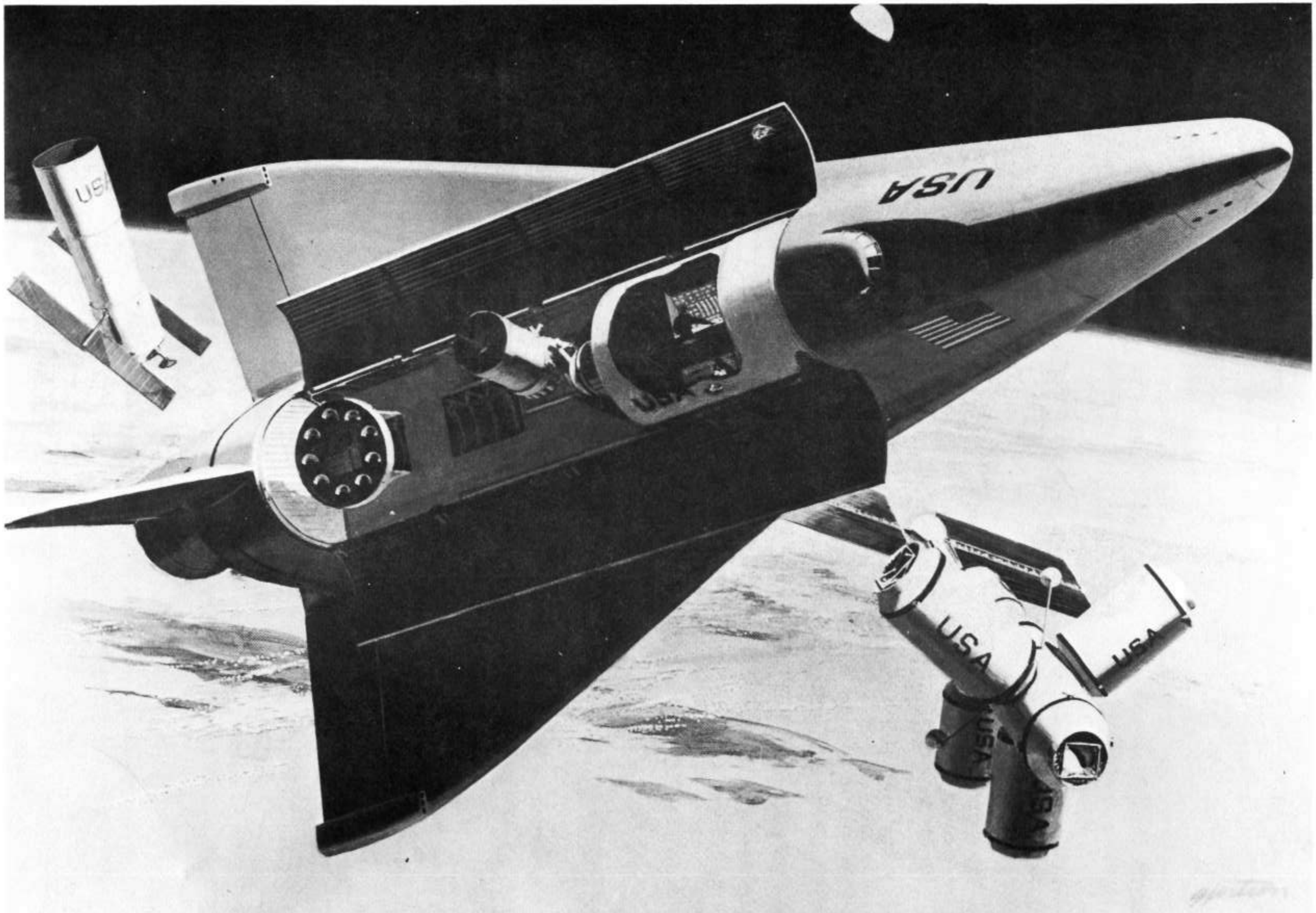


72-1827


USA


USA
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